OFFICIAL PUBLICATION OF THE PROCEEDINGS AMERICAN ASSOCIATION OF TEXTILE CHEMISTS AND COLORISTS

SEPTEMBER 3, 1951
VOLUME 40, No. 18

AMERICAN DYESTUFF REPORTER

DEVOTED TO TEXTILE CHEMISTRY • BLEACHING • DYEING • PRINTING • FINISHING

DU PONT "CAPRACYL"* neutral dyeing colors have been specifically developed to give the highest possible light and wet fastness on both filament and staple nylon. They can be applied in the same short time cycle as acid dyes.

These new dyes, such as "Capracyl" Red B, are especially recommended for dyeing nylon staple. Fabrics made from staple dyed with these new colors provide the superior light fastness needed for upholstery materials, outerwear, pile fabrics, suitings, automotive top materials, government fabrics and infants' wear. They are also suitable for dyeing wool, giving similar fastness properties.

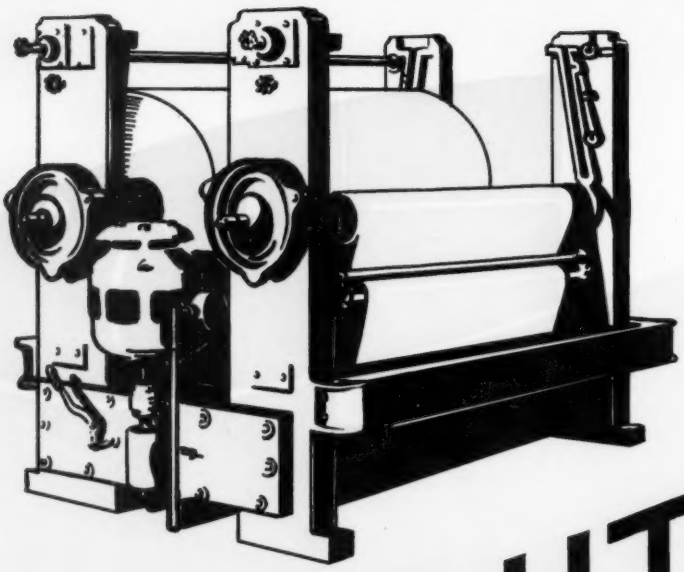
For information on the "Capracyl" dyes — or for help on any coloring problem — consult our Technical Staff. E. I. du Pont de Nemours & Co. (Inc.), Dyestuffs Division, Wilmington 98, Delaware.

*TRADE MARK

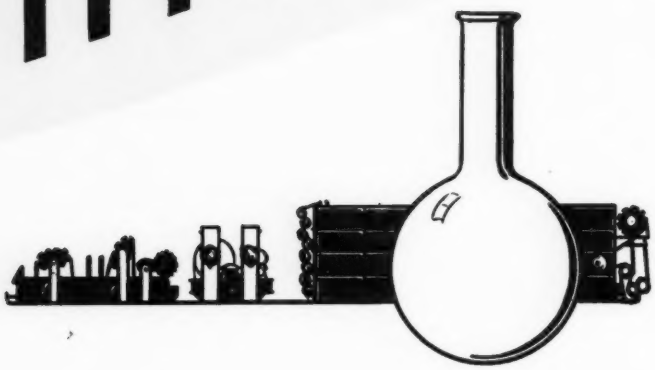
Du Pont Dyestuffs

DUPONT
REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY



NAPHTHOLS



Wherever you find
the textile industry—
you will find
Napthols and Beta Oxy Naphthoic Acid . . .

MANUFACTURED BY

Pfister Chemical Works INC.

RIDGEFIELD NEW JERSEY

helping you
make
COLOR
behave

One sure step towards consistent color satisfaction in dyeing and printing is to investigate the A.A.P. textile auxiliaries listed below. Technicians from our nearest branch will be happy to show how each has helped leading dyers, finishers and printers... *how each can help you.*

★ **LEVELENE** For wetting-out...preparing... dyeing...finishing. Dependable as a vat dyeing retardant and as a vat stripper.

★ **FASTOGENE** Gives amazing water-fastness in a simple after-treatment. For dyeing—printing—finishing of cottons, multifibres.

★ **STABILON** A *must* with Napthols. *Minimizes* crocking and brightens Napthol shades.

★ **DEPUMA** An *antifoaming* agent for printing—dyeing—soaping. Breaks foam in dye liquors and print pastes *without emulsifying or evaporating.*

For full information on these and other A.A.P. products, along with data pertinent to your individual problems, consult our nearest branch.

AMERICAN ANILINE PRODUCTS, INC.

50 Union Square, New York, N. Y.
Plant: Lock Haven, Pa.
Branches: Boston, Mass. • Providence, R. I.
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Dominion Anilines & Chemicals, Ltd.
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*Reg. U. S. Pat. Off.

UP·GRADE
YOUR FABRICS WITH PROFINE!

One of the biggest advantages you'll find in using Profine is the *control* it gives you over a fabric's softness, body and hand.

If you want a soft, full-bodied hand for your knitted and woven fabrics, you can get it with Profine. If you want good whites that don't discolor, you'll get them with Profine. If you want good anti-curl cutting, you'll get it with Profine.

Profine is made-to-order for up-grading fabrics . . . increasing their salability. A month's trial will prove it—to *your* satisfaction.

FACTS ABOUT PROFINE

Fast dissolving flake form. Self-emulsifiable. Stable emulsions.
Imparts softness or body to fabrics and yarns.
No effect on shade.
Inhibits static.
No tendency to form objectionable odors or discoloration.

Profine

Procter & Gamble
CINCINNATI, OHIO

MAKERS OF OLATE, PROXOL AND ORVUS PRODUCTS.

American Dyestuff Reporter, Vol. 40, No. 18, September 3, 1951. Published every other Monday. Copyright 1951, by Howes Publishing Co., Inc., 44 E. 23rd St., New York 10, N. Y. Domestic subscriptions, $5.00; Canadian, $6.00; Foreign, $10.00. Entered as second-class matter, Nov. 6, 1919, at the New York, N. Y., Post Office, under the act of March 3, 1879.

CIBA PRINTING BLACK AR PASTE NEW

"The" Printing Black for fabrics of

VISCOSE RAYON • VISCOSE & ACETATE MIXTURES • COTTON

This exceptionally fine black is time-tested for shade fastness, non-drying, and economy. Send for complete information on properties and applications.

CIBA COMPANY INC.

627 GREENWICH STREET, NEW YORK 14, N. Y.

Boston Chicago Charlotte
Providence San Francisco Philadelphia

Direct Dyed

but triple fast

Not just fast to laundering and perspiration—fast to light, too!

Yes, CUPROFIX colors and after-treatment give cotton and rayon fabrics such a high degree of fastness *to all three* . . . that direct dyeing now compares favorably with more expensive vat dyeing!

But *only* with CUPROFIX can you expect direct-dyed fabrics to have satisfactory fastness to *sunlight.* Only CUPROFIX gives you triple fastness in direct dyeing.

Economy—and Quality, too!

You save many dollars when you use direct dyes. For pennies more—relatively—you can make the big saving *without* sacrificing quality . . . and compete successfully with many vat-dyed fabrics.

Get acquainted with CUPROFIX now—write us for Booklet U. S. 125. SANDOZ CHEMICAL WORKS, INC., 61 Van Dam St., New York 13, N.Y.

Label Resin-Treated Garments "WASHABLE"

Adding CUPROFIX to the resin bath increases fastness to washing sufficiently to permit labeling garments "washable" instead of just "dry cleanable". It also:

materially increases efficiency of the usual resin treatment

eliminates in many cases the effect of resin on light fastness.

SANDOZ CHEMICAL WORKS, Inc.
61 Van Dam Street, New York 13, N. Y. Application laboratories and stocks at Boston, Philadelphia, Charlotte, Los Angeles, Toronto. Other branches at Providence, Paterson, Chicago.

Fast to Light - Wash - Perspiration
Pressing - Cleaning

CUPROFIX

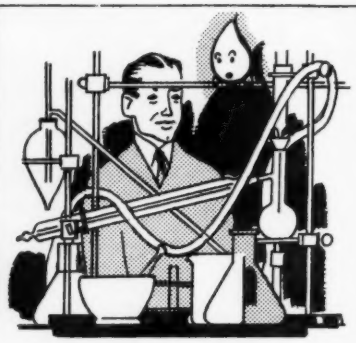
BY SANDOZ

SANDOZ *thinks ahead with textiles*

SANDOZ

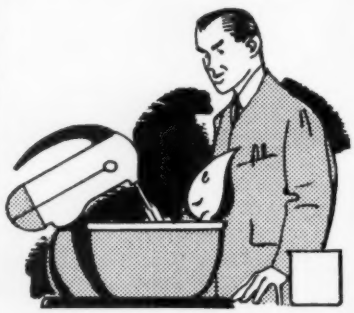
We "*challenge*" you to give PENN-DRAKE® White Oils the works!

Accept our sample, turn it over to your chemist and let him analyze it most critically.



Try to detect some impurity or lack of stability.

Try to find some trace of odor, color or taste.



Compare its properties—point by point—with the material you are now using.

Check your findings against your specifications, or against your accepted standards for purity and performance.

Add up the score, compare the cost, and you will find you should be using Penn-Drake WHITE OILS!

Typical Applications in the Textile Industry

PENN-DRAKE OFFERS WHITE OILS HAVING ALL THE QUALITIES NEEDED FOR THE *WILLIAMS HOT OIL DYEING PROCESS*, AS WELL AS A COMPLETE LINE OF WHITE OILS FOR THE PROCESSING OF RAYON AND OTHER SYNTHETIC FIBRES AND FOR THE FORMULATION OF YARN LUBRICANTS, FINISHING, CONING AND OTHER OILS.

Because we take extra care in refining the best petroleum stocks, we're confident that Penn-Drake White Oils will stand up well under the most rigid tests you can give them. They are odor-free, tasteless, colorless, completely free from the acids, alkalies and all other impurities which might cause your product to deteriorate with age, and the purity is locked in by a U.S.P.-approved stabilizer. The price is low enough so any quality product can afford Penn-Drake White Oils.

If a regular White Oil won't do for you, write your own specifications and we will follow them exactly in giving you a White Oil with the "slightly different" characteristics you need. *May we send our sample?*

penn drake products

PENNSYLVANIA REFINING COMPANY

GENERAL OFFICES: BUTLER, PENNSYLVANIA

Refinery at KARNS CITY, PENNSYLVANIA

Branches: Cleveland, Ohio; Edgewater, N. J. *Representatives in Principal Cities*

MAKERS White Oils (U.S.P., N.F. and Technical), Petrolatums (all grades and colors); INSECTI-SOL (deodorized insecticide base); Deodorized and other Naphthas; Petroleum Sulfonates; Waxes; Industrial and Motor Lubricants and Greases; Fuel Oils, and other petroleum products.

ottomans bengalines

IN THE NEW ITALIAN STYLES

Bloomy shades of black on viscose rayon or cotton with acetate reserved — and excellent resistance to light, washing and perspiration!

With Cuprophenyl Black RL* a fast black can be produced in considerably shorter processing time than is required for more fugitive blacks. Acetate is reserved or can be cross-dyed in delicate pastels or deep shades, *in the same dyebath*, with ease of application either in the jig or in the dye-bek.

Cuprophenyl Black RL has good resistance to urea formaldehyde or melamine resin finishing.

Booklet #20-G gives complete data and samples are available for trial.

* Patented

Geigy

Dyestuff Makers Since 1859

GEIGY COMPANY, *Inc.*

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Your Most Logical Source for the Finest Textile

Colors

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In Daylight or Lamplight

THE SHADE STAYS THE SAME

With Selected Interchem Acetate Dyes

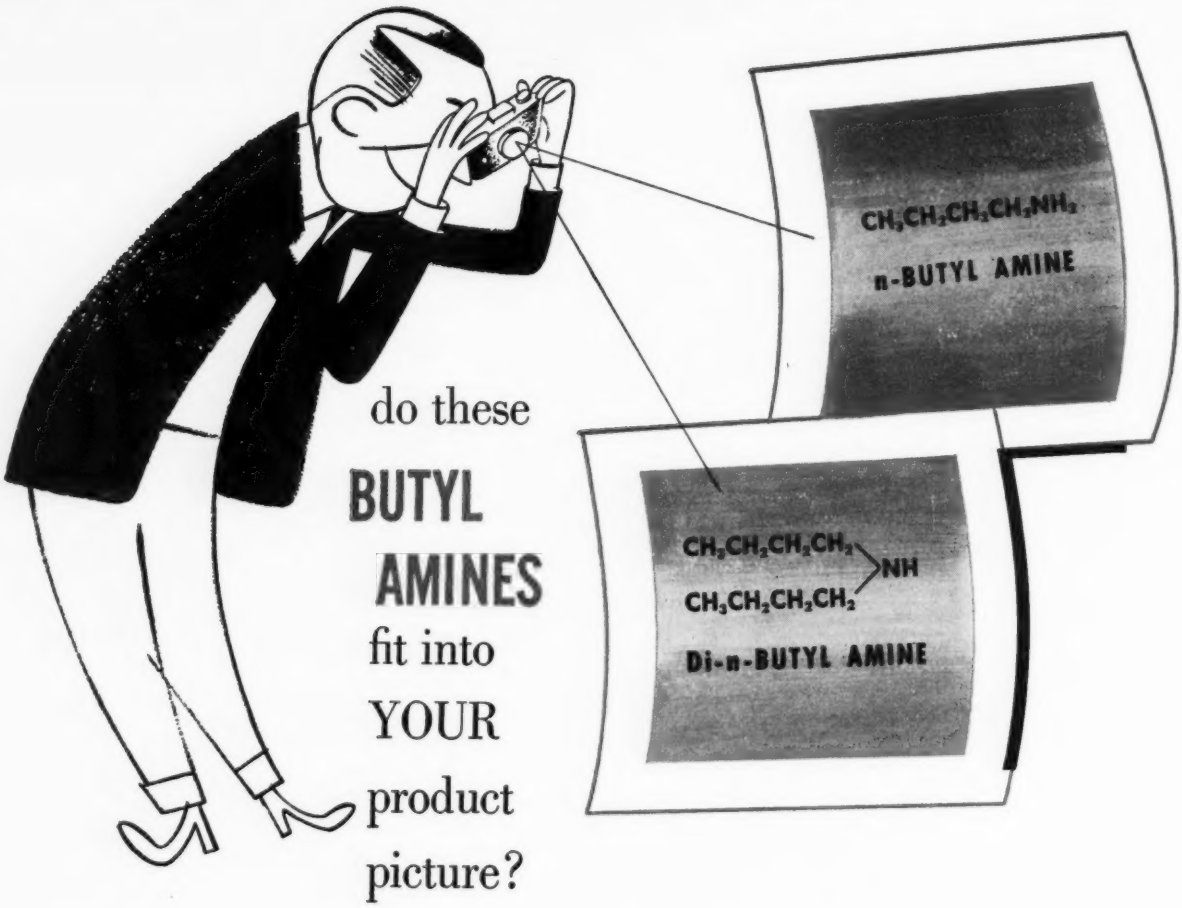
Why run the risk of having fabrics returned because the shades change in artificial light! Interchemical technicians developed a series of color combinations to give you minimum shade change in different lights. They're well suited for all-acetate fabrics and help solve the complex problems in dyeing wool and acetate blends.

These special combinations of Interchem Acetate Dyes are another reason why Interchemical is your most logical source of supply for the finest textile colors. They provide good all-round fastness for men's wear, women's wear, carpets and draperies. Write for full details today.

Aridye PIGMENT COLORS Reg. U.S. Pat. Off.

Interchem Dyes Reg. U.S. Pat. Off.

Arigen Dyes Reg. U.S. Pat. Off.



do these BUTYL AMINES fit into YOUR product picture?

How you can use them . . .

- fatty acid soaps of butyl amines are useful for preparing water-in-oil emulsions.
- these amines have utility in the preparation of:

specialty soaps	corrosion inhibitors
dyestuffs	petroleum demulsifiers
rubber chemicals	insecticides
flotation agents	pharmaceuticals

Butyl Amine and Dibutyl Amine may be just the answer to your product or process problem. Check them now by asking for samples and information on your company letterhead. Be sure to ask for technical bulletin F-6871A, "Butyl Amines."

CARBIDE AND CARBON CHEMICALS COMPANY
A Division of
Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.

Offices in Principal Cities
In Canada:
Carbide and Carbon Chemicals, Limited, Toronto

MORE THAN 60 OTHER AMINES

When you are considering alkyl amines, keep in mind that CARBIDE also supplies Ethyl, Diethyl, Triethyl, Isopropyl, Diisopropyl, 2-Ethylhexyl, and Di(2-Ethylhexyl) amines. But that's not all! CARBIDE also makes more than 60 other amines. Get a complete list of these by asking for our 1952 edition of "Physical Properties of Synthetic Organic Chemicals," Form 6136.

Wyandotte Chemicals
REG. U. S. PAT. OFF.

DEVELOPMENT NEWS

PLURONICS DEMONSTRATE WORTH IN MANY TEXTILE APPLICATIONS

New Series of Nonionic Surface Active Agents Offers Advantages Where Wetting and Penetrating Ability Plus A-1 Detergency and Complete Rinsability Are Required

Though recently introduced, the Pluronics have won quick acceptance in many textile applications. Users have commented on their stability, effectiveness in low concentrations, low-foaming power and complete rinsability.

Developed by Wyandotte, the Pluronics are surface active agents of unusually high molecular weight. New and different, they often exercise synergistic effects with many types of colloidal materials.

Four of the series—Pluronic L44, Pluronic L62, Pluronic L64 and Pluronic F68—are available in pilot quantities. Pluronic F68 is in the form of free-flowing white flakes, 100% active. For complete information, use the coupon.

Pluronic F68. First commercially available 100% active agent nonionic detergent in free-flowing flake form.

PLURONICS OFFER FOUR ADVANTAGES

1. Because of their ether type structure, Pluronics are extremely stable to acids, alkalies and electrolytes.
2. Pluronics are effective in low concentrations, with resulting savings in materials.
3. Pluronics are practically nonfoaming under use conditions.
4. Pluronics promote complete rinsability, help to get soap out (if there is soap) and rinse freely themselves.

PLURONICS WITH WOOL

When properly built with alkaline or neutral salts, the Pluronics are recommended for raw wool scouring. Where lanolin is recovered, the use of a Pluronic of a relatively low degree of emulsifying power results in easier lanolin recovery.

Pluronics show promise as dye leveling assistants. Their stability to acids and metal salts also suggests their use as wetting agents for wool carbonizing and fulling.

PLURONICS WITH RAYON, SILK AND NYLON

The Pluronics offer effective use in scouring silk, nylon and rayons.

At low concentrations, the Pluronics are effective agents for the removal of many sizes.

PLURONICS WITH COTTON

In the manufacture of cotton fabrics, the Pluronics have shown their usefulness in many applications including kier boiling, desizing, boiling off, dye leveling and soaping off.

Wyandotte
REG. U. S. PAT. OFF.

DEVELOPMENT DEPARTMENT, AD-9

WYANDOTTE CHEMICALS CORPORATION, Wyandotte, Michigan

Please send me Pluronics booklet and additional information on their use in .....

Name_____

Company_____

Address_____

City_____ **State**_____

What Do You Look For in a Stearic Acid?

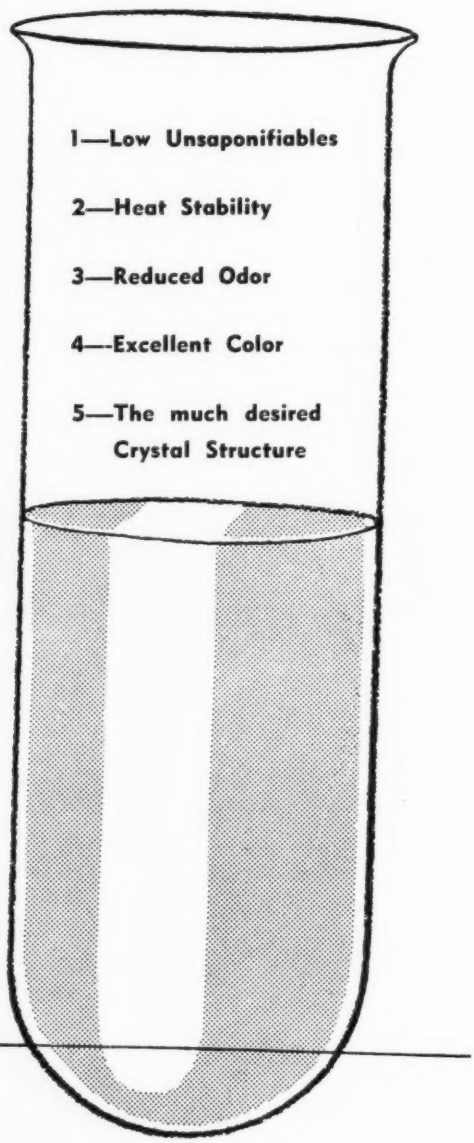
You can have them all in
A. Gross Stearic Acid.

Through years of constant research and development, employing the most modern equipment, A. Gross has maintained the natural balance of palmitic and stearic acid found in tallow as indicated by the excellent crystal structure of our Stearic Acid.

In looking for a choice Stearic Acid demanded by the discriminating manufacturer of cosmetics, food emulsifiers, pharmaceuticals, or any other products utilizing stearic acid, the answer is

Manufacturers Since 1837

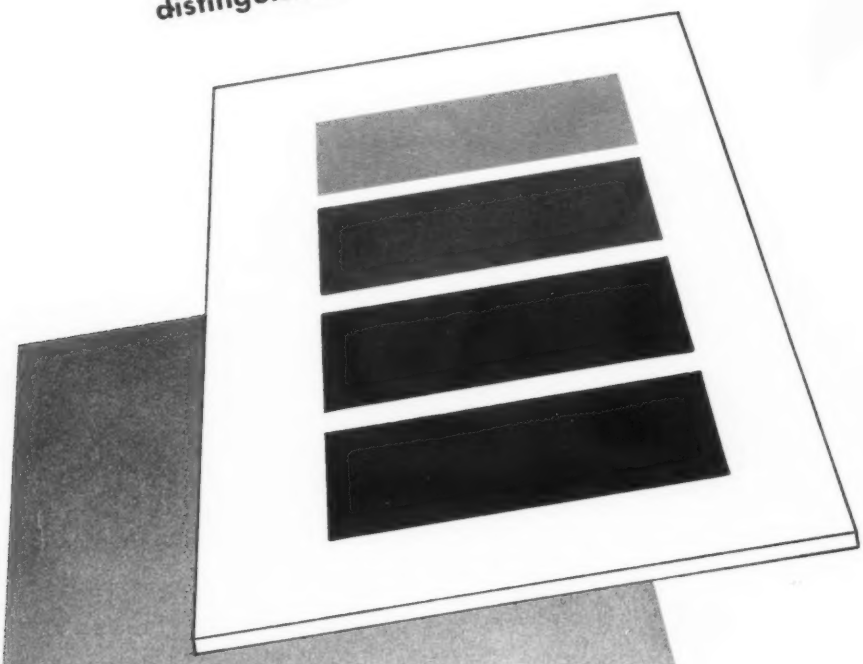
A. GROSS & Company
295 MADISON AVE., NEW YORK 17, N.Y.
FACTORY: NEWARK, N.J.



Shade with a place in the sun

SOLANTINE RED 6BLL

Direct cotton and rayon color distinguished for its light fastness



- **All the economy and ease of application inherent in direct dyes plus excellent Light Fastness.**
- **Does not stain acetate effect threads.**
- **Excellent value for use on dry cleanable outerwear, sports dresses, etc.**

For shade card, write, wire or phone our nearest office.

NATIONAL ANILINE DIVISION

ALLIED CHEMICAL & DYE CORPORATION

40 RECTOR STREET, NEW YORK 6, N.Y. • BOwling Green 9-2240

Boston 14, Mass., 150 Causeway St	CApitol 7-0490	Richmond 19, Va., 8 North Fifth St.	Richmond 2-1930
Providence 3, R.I., 15 Westminster St	DExter 1-3008	Columbus, Ga., Columbus Interstate Bldg.	Columbus 3-1029
Philadelphia 6, Pa., 200-204 S. Front St	LOmbard 3-6382	Greensboro, N.C., Jefferson Standard Bldg.	GReensboro 2-2510
San Francisco 5, Cal., 517 Howard St	SUtter 1-7507	Chattanooga 2, Tenn., James Building	CHattanooga 6-6347
Portland 9, Ore., 730 West Burnside St	Beacon 1853	Atlanta 2, Ga., 140 Peachtree St	CYPress 2821
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Charlotte, 1 N.C., 201-203 West First St	CHarlotte 3-9221	Toronto 2, Canada, 137-143 Wellington St. W	Elgin 6495

"light soaping is enough!"

—TO RINSE PRINTING THICKENER OUT COMPLETELY

AMBERFLO, a highly soluble printing thickener, deposits a soft print. Light washing rinses it out quickly. Easily. Completely. Using tap water. Result? Happier production men. And fabrics that warm a fashion designer's heart with their softness . . . sparkling color . . . finer hand and body.

AMBERFLO eliminates cooking, cooling and expensive mixing equipment. Simply blend it with chemicals and water. In a few minutes, the "color" is ready. Splitting is minimized on "Sheers" and other fragile fabrics, because it deposits a smooth, pliable film. Color yield is higher. Penetration and detail are excellent.

AMBERFLO is recommended for vat, rapidogen, direct, acid and acetate colors. Also white discharge.

National Starch Products,
270 Madison Avenue, New York 16, N. Y.

National
STARCH PRODUCTS

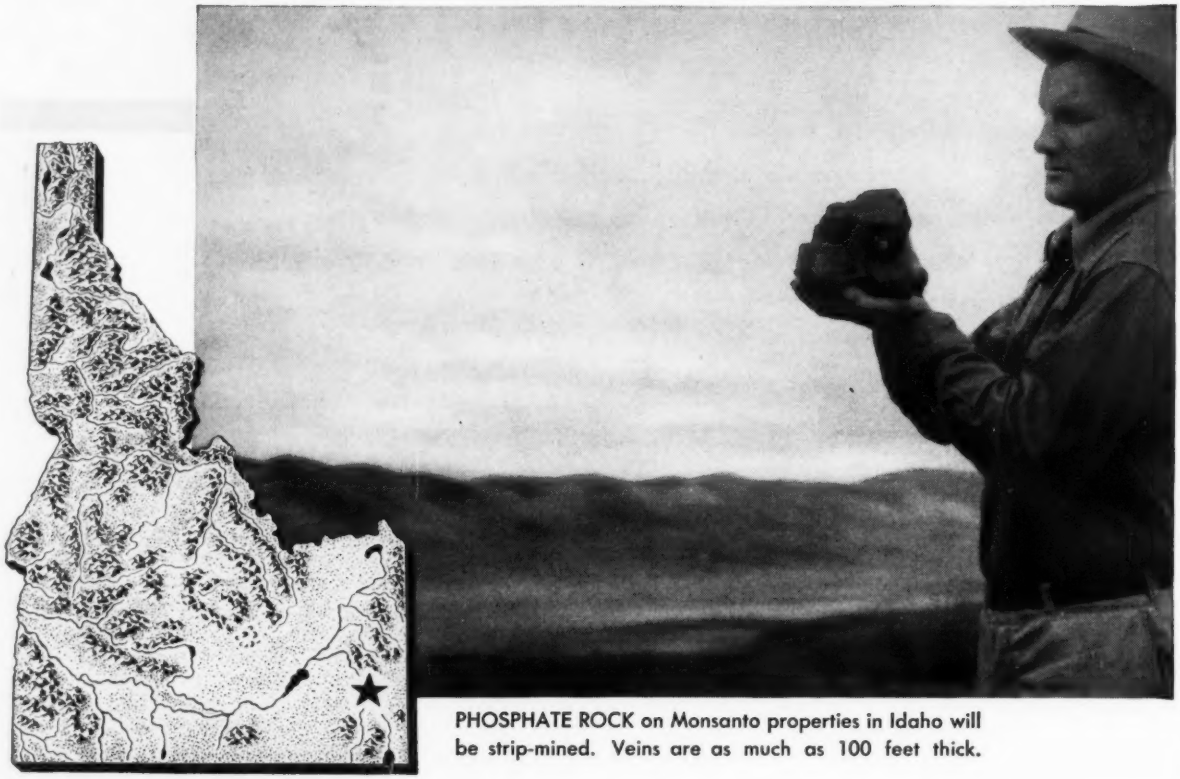
We want to know more!

We're interested in AMBERFLO—National's easy-rinsing, ready-for-use printing thickener.

☐ *We want more technical data.*
☐ *We'd like a plant demonstration.*

Name_____ Title_____
Company_____
Address_____
City_____ Zone_____ State_____

MONSANTO Expands



PHOSPHATE ROCK on Monsanto properties in Idaho will be strip-mined. Veins are as much as 100 feet thick.

Monsanto, already the world's largest producer of elemental phosphorus, has added extensive holdings of phosphate rock near Soda Springs, Idaho. To extract elemental phosphorus of better than 99.9% purity from this rock, Monsanto is constructing a large electric furnace plant at Soda Springs, Idaho.

The output of this furnace plant, available next year, will substantially increase Monsanto's production of elemental phosphorus. It will mean more phosphoric acid and its derivatives for myriad industries using such products.

Elemental phosphorus from the Soda Springs furnace plant will travel by rail to Monsanto plants in Monsanto, Illinois; St. Louis, Missouri; Trenton, Michigan; and Anniston, Alabama; where it is converted into pure phosphoric acid and numerous phosphates serving hundreds of industries. Expansion of manufacturing facilities at these processing plants is under way.

SINCE 1937, Monsanto has been producing elemental phosphorus at its Monsanto, Tennessee, plant and today there are six large electric furnaces in the Monsanto, Tennessee, installation shown at the left. Monsanto originated the present-day method of large-volume elemental phosphorus production and was the first to ship the element in tank-car quantities.

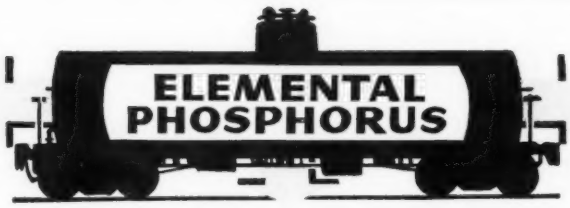
Phosphorus Production

MORE PHOSPHORUS = MORE PHOSPHORIC ACID, MORE PHOSPHATES, MORE PHOSPHORUS DERIVATIVES

Phosphorus Pentoxide

Phosphorus burned in dry air produces phosphorus pentoxide from which these products are derived:

Methyl Phosphoric Acid
Ethyl Phosphoric Acid
Propyl Phosphoric Acid
Butyl Phosphoric Acid
Amyl Phosphoric Acid



PHOSPHORIC ACID

Phosphorus burned in moist atmosphere produces phosphoric acid used in various industries and from which sodium phosphates, calcium phosphates, ammonium phosphates, potassium phosphates and numerous other phosphates are derived.

Phosphorus Trichloride

Phosphorus plus chlorine produces phosphorus trichloride from which the following are derived:

Triethyl Phosphite
Phosphorus Oxychloride
Triethyl Phosphate
Tributyl Phosphate
Trioctyl Phosphate
Tricresyl Phosphate
Triphenyl Phosphate

SODIUM PHOSPHATES

Mono Sodium Phosphate
Uses:
Acid Cleaners
Water treatment
Textiles

Di Sodium Phosphate
Uses:
Cheese
Leather
Textiles
Detergents
Water treatment
Dye
Pigments

Tri Sodium Phosphate
Uses:
Water softening
Detergent
Metal cleaning
Water treatment
Textiles

Tetra Sodium Pyrophosphate
Uses:
Soap
Textiles
Detergents
Clay dispersant
Dyeing
Bleaching
Pitch control
Metal cleaning
Oil well drilling
Water treatment
Water softening
Glass

Sodium Acid Pyrophosphate
Uses:
Baking powder
Oil well drilling
Electroplating
Prepared flour

CALCIUM PHOSPHATES

Mono Calcium Phosphate
Uses:
Baking powder
Self-rising flour
Self-rising corn meal
Prepared flour
Food enrichment

Di Calcium Phosphate
Uses:
Tooth paste
Tooth powder
Food enrichment
Pharmaceutical

Tri Calcium Phosphate
Uses:
Tooth paste
Tooth powder
Anticaking agent
Food enrichment
Pharmaceutical

Tetra Calcium Pyrophosphate
Uses:
Food enrichment
Pharmaceutical

Sodium Polyphosphate
Uses:
Oil well drilling
Textiles
Water treatment
Detergents

Sodium Tripoly Phosphate
Uses:
Detergents
Pitch control
Metal cleaners
Water treatment
Clay dispersant

PHOSPHORIC ACID

Uses:
Soft drinks
Rustproofing
Metal cleaning
Gelatin
Jelly and preserves
Silage treatment
Fertilizer
Textiles
Sugar
Pharmaceutical
Water treatment

AMMONIUM PHOSPHATES

Mono Ammonium Phosphate
Uses:
Flameproofing
Yeast
Malt
Plant nutrient
Acid cleaners

Di Ammonium Phosphate
Uses:
Flameproofing
Yeast
Plant nutrient
Ammoniated dentifrices

POTASSIUM PHOSPHATES

Mono Potassium Phosphate
Uses:
Pharmaceutical
Plant nutrient

Di Potassium Phosphate
Uses:
Fermentation
Pharmaceutical
Nutrient solutions

Tri Potassium Phosphate
Uses:
Oil refining

Tetra Potassium Pyrophosphate
Uses:
Soap
Textiles
Water softener
Synthetic rubber manufacture

OTHER PHOSPHATES

Iron Phosphates
Magnesium Phosphates
Aluminum Phosphates
Barium Phosphates
Beryllium Phosphates
Copper Phosphates
Lead Phosphates
Lithium Phosphates
Silver Phosphates
Zinc Phosphates

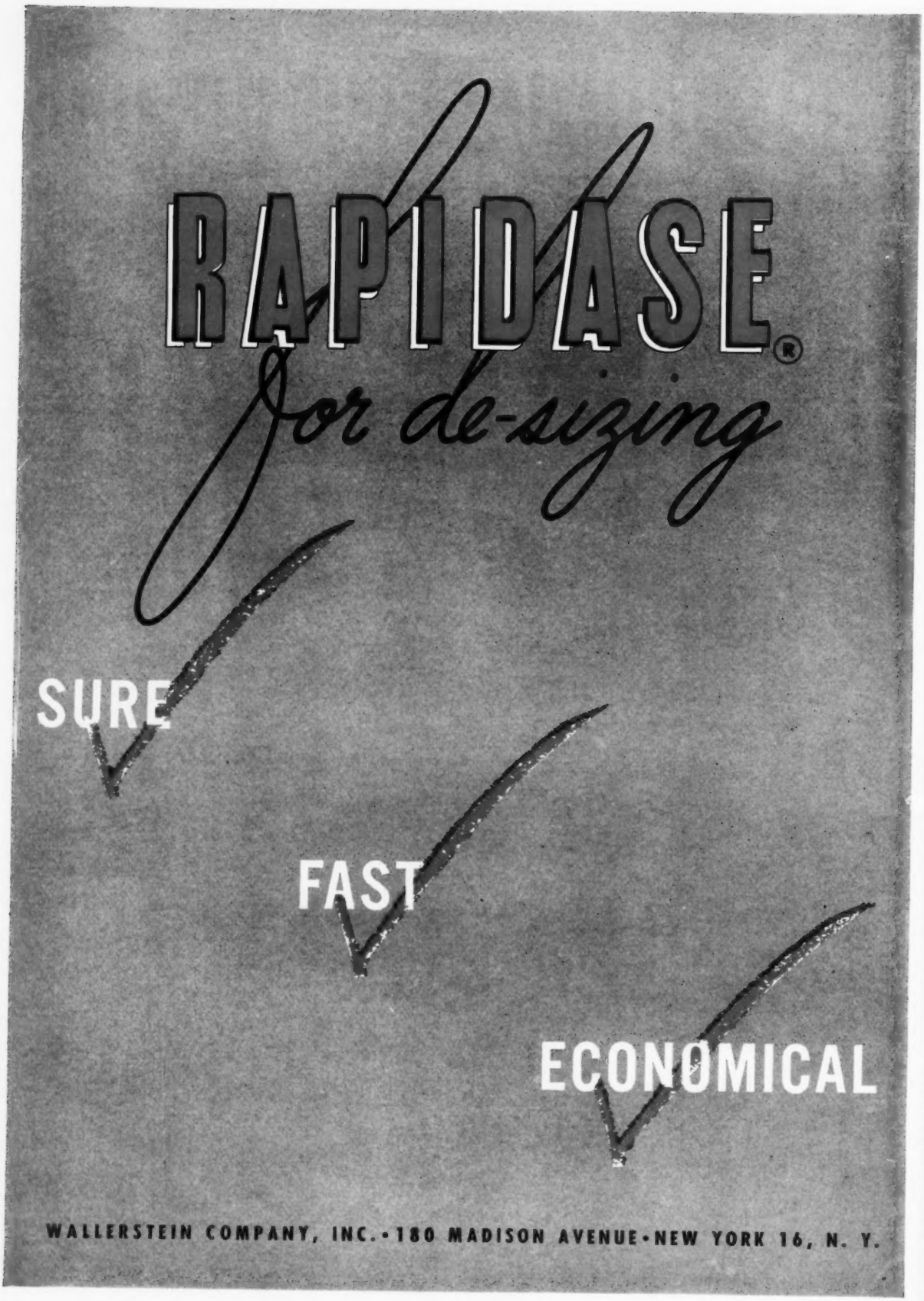
MONSANTO
CHEMICALS AND PLASTICS
®

SERVING INDUSTRY . . . WHICH SERVES MANKIND

FOR INFORMATION on Monsanto's chemically pure phosphoric acid and phosphates, contact the nearest Monsanto Sales Office or write MONSANTO CHEMICAL COMPANY, Phosphate Division, 1700 South Second Street, St. Louis 4, Missouri.

☆ ☆ ☆

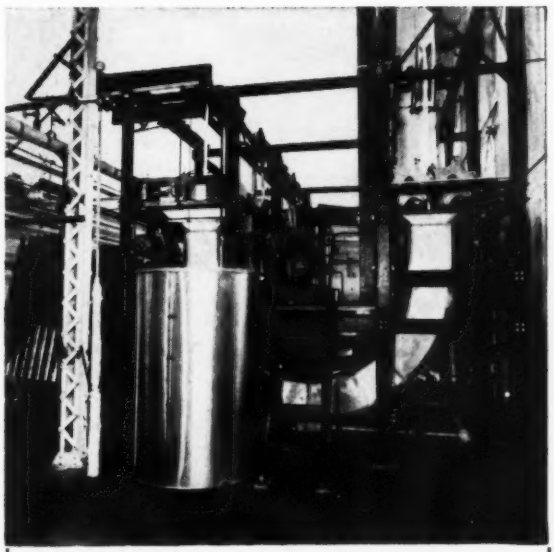
DISTRICT SALES OFFICES: Birmingham, Boston, Charlotte, Chicago, Cincinnati, Cleveland, Detroit, Los Angeles, New York, Philadelphia, Portland, Ore., San Francisco, Seattle. In Canada, Monsanto (Canada) Ltd., Montreal.


RAPIDASE®
for de-sizing
SURE
FAST
ECONOMICAL
WALLERSTEIN COMPANY, INC. • 180 MADISON AVENUE • NEW YORK 16, N. Y.

HOW TO SAVE MONEY ON SMALL-VOLUME BLEACHING

get increased uniformity . . . faster bleaching . . . lower bleaching costs

By Du Pont Continuous Peroxide Bleaching with the Butterworth "Junior" Unit



This two-stage Butterworth-Du Pont "Junior" Unit at Kerriglen Finishing Company, Providence, Rhode Island, has been in regular operation since May, 1950.

Archie Stevenson, President of Kerriglen, writes:

"Our 'Junior' Bleaching Range is producing between 3500 and 4000 yards per hour of 80 x 80 cotton print cloth suitably bleached for our printing process. Through use of the unit, there has been an appreciable saving in bleaching costs.

"The bleached cloth is extremely uniform and the full strength of the cloth is apparently retained."

If your requirements call for a production capacity of 500 to 1,000 lbs. per hour, the Butterworth-Du Pont "Junior" Continuous Peroxide Bleaching Unit can give you the same low-cost, high-quality results that are possible with full-scale ranges.

This job-tested, space-saving bleaching system has been designed expressly for small-scale and specialty work. It is particularly suited for use in the following types of plants:

1. Small bleacheries and mills producing 100,000-300,000 yards per week of white goods, goods for dyeing and printing, colored yarn shirtings and fancy dress goods, or any combination thereof, in the 3-7 yds./lb. class.

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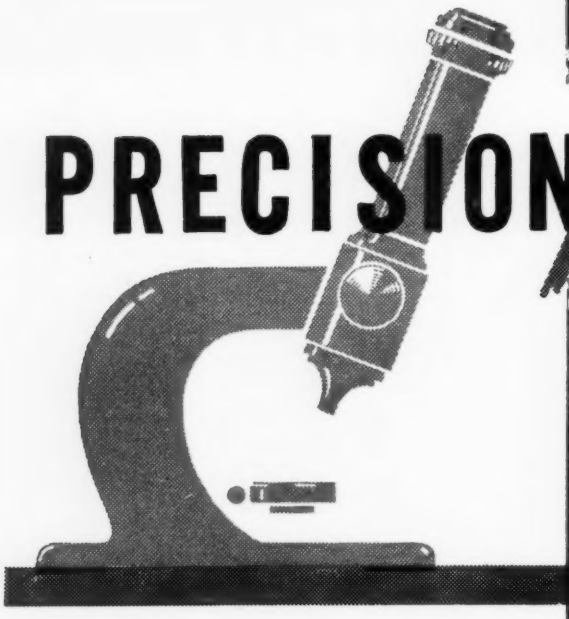

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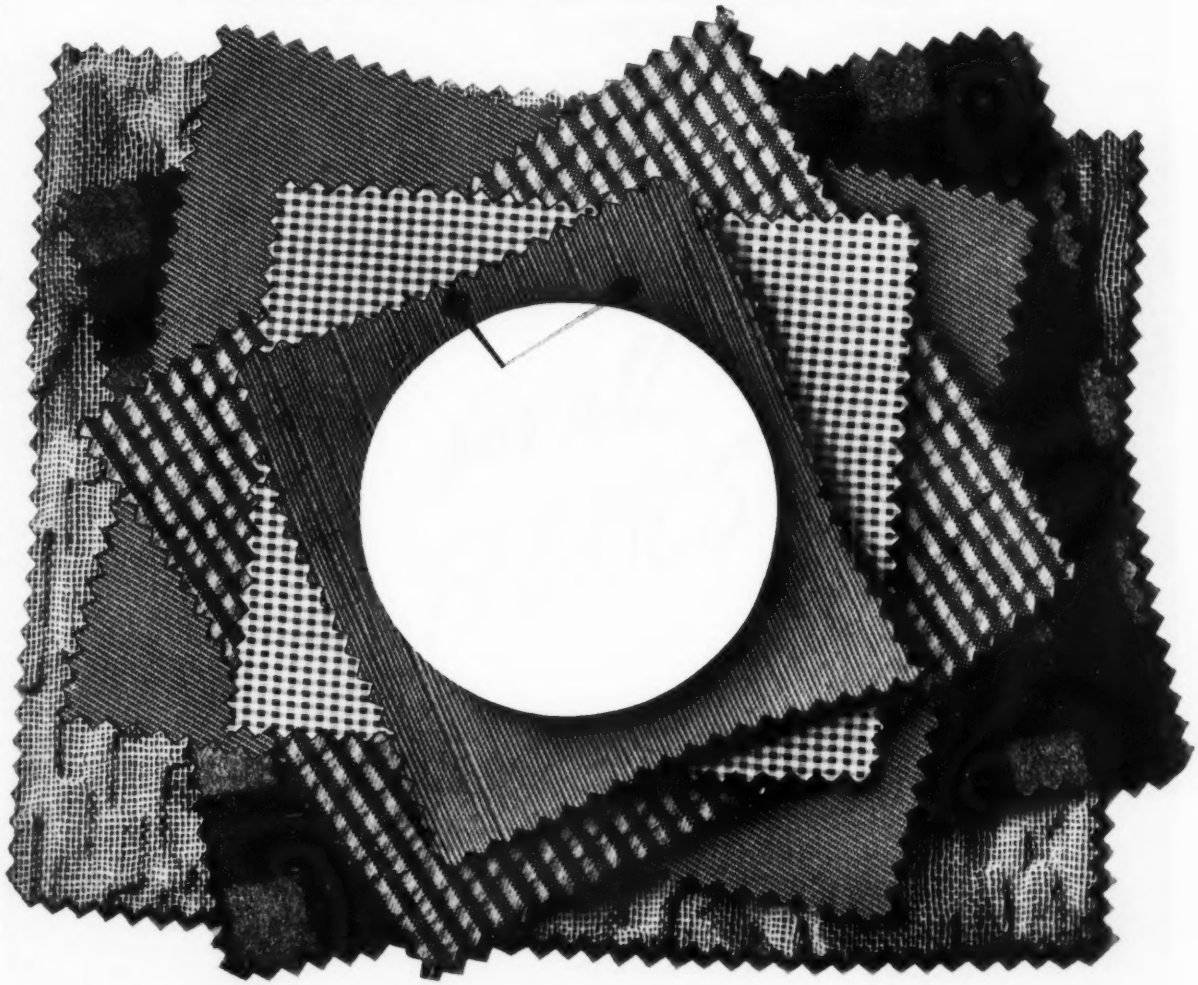

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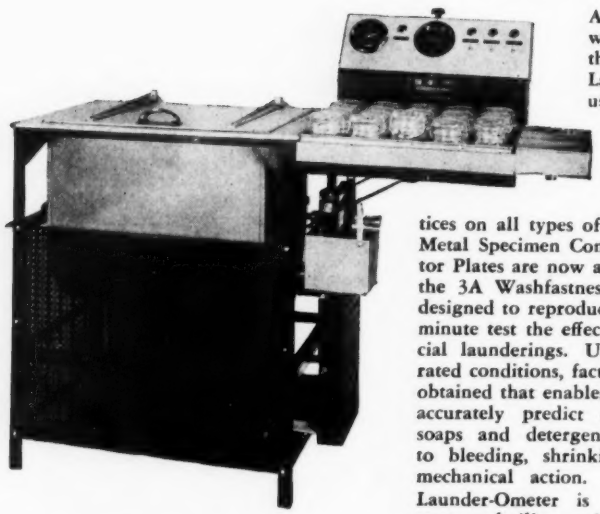

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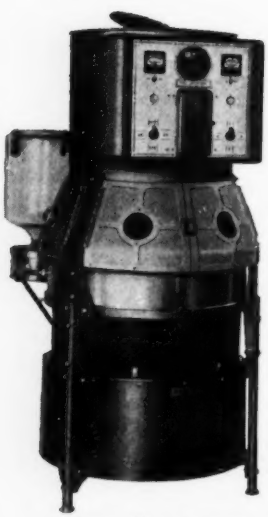

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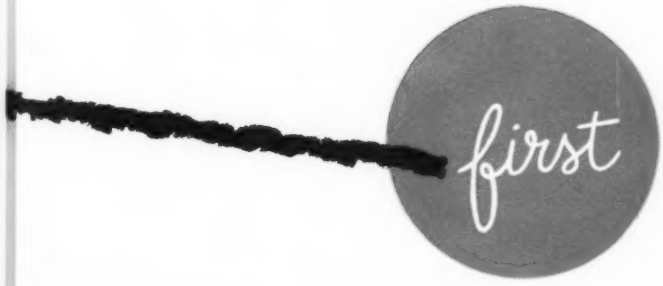

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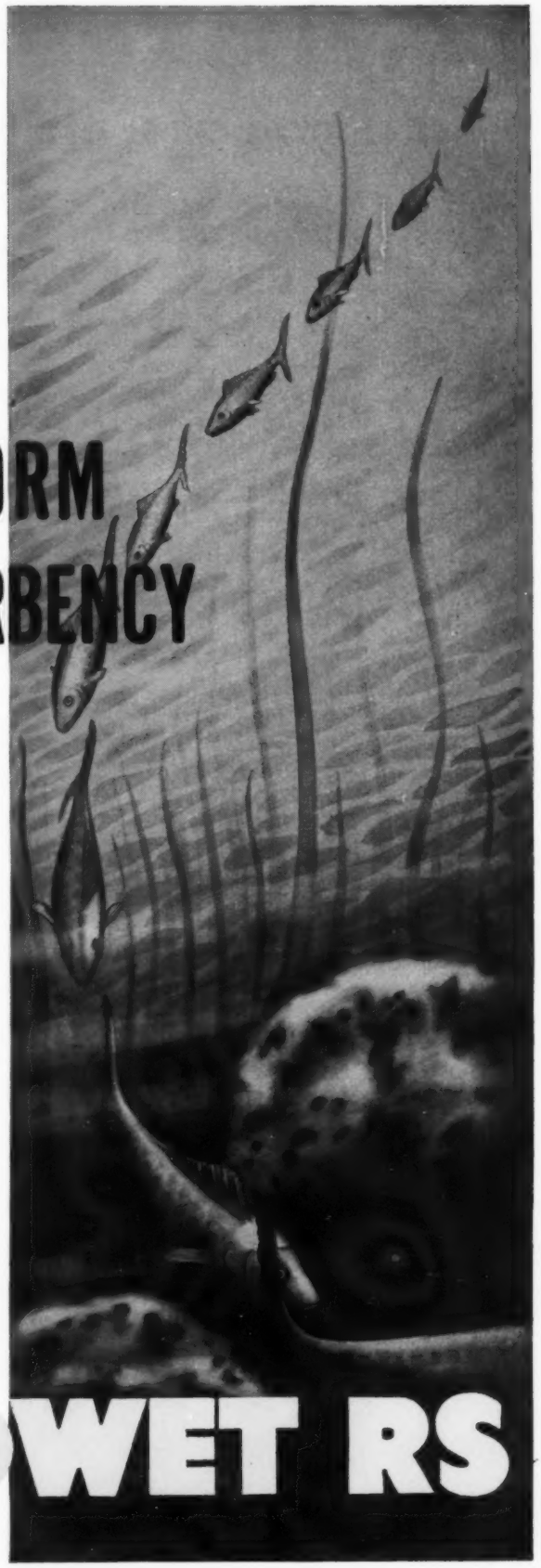

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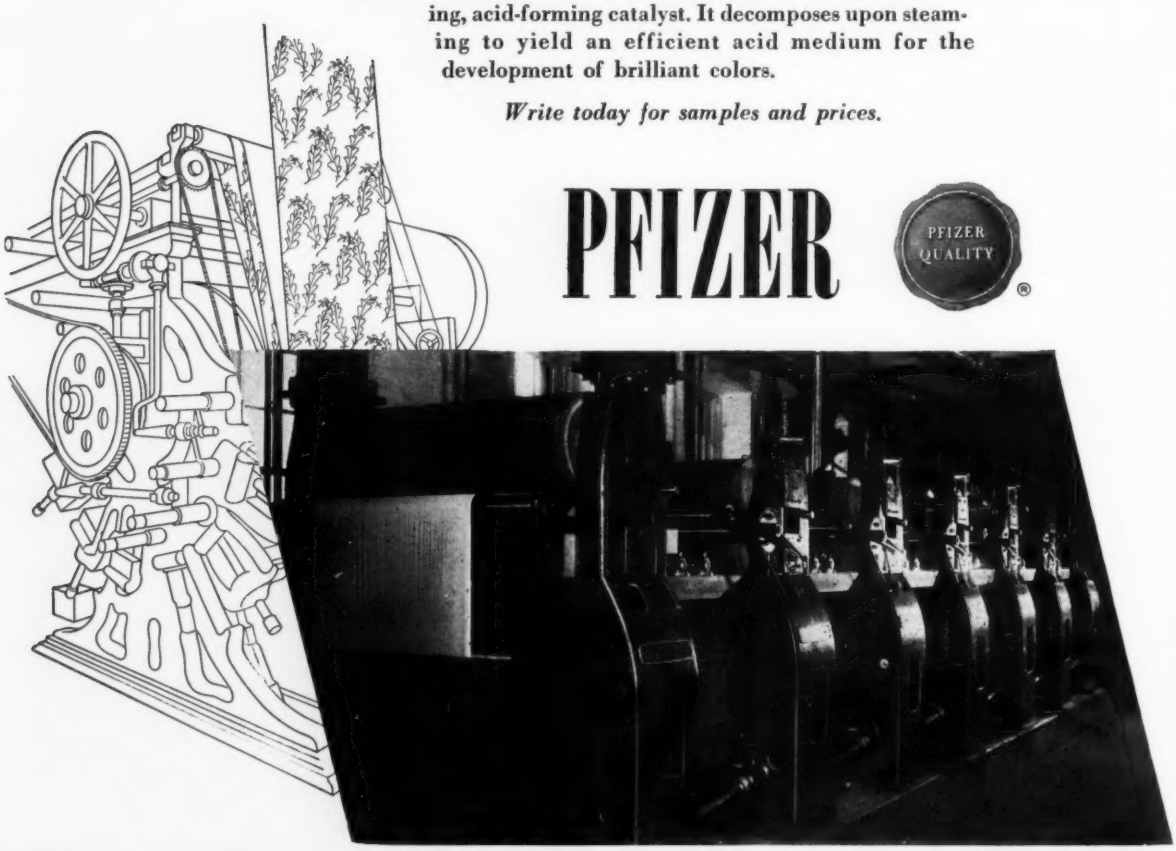

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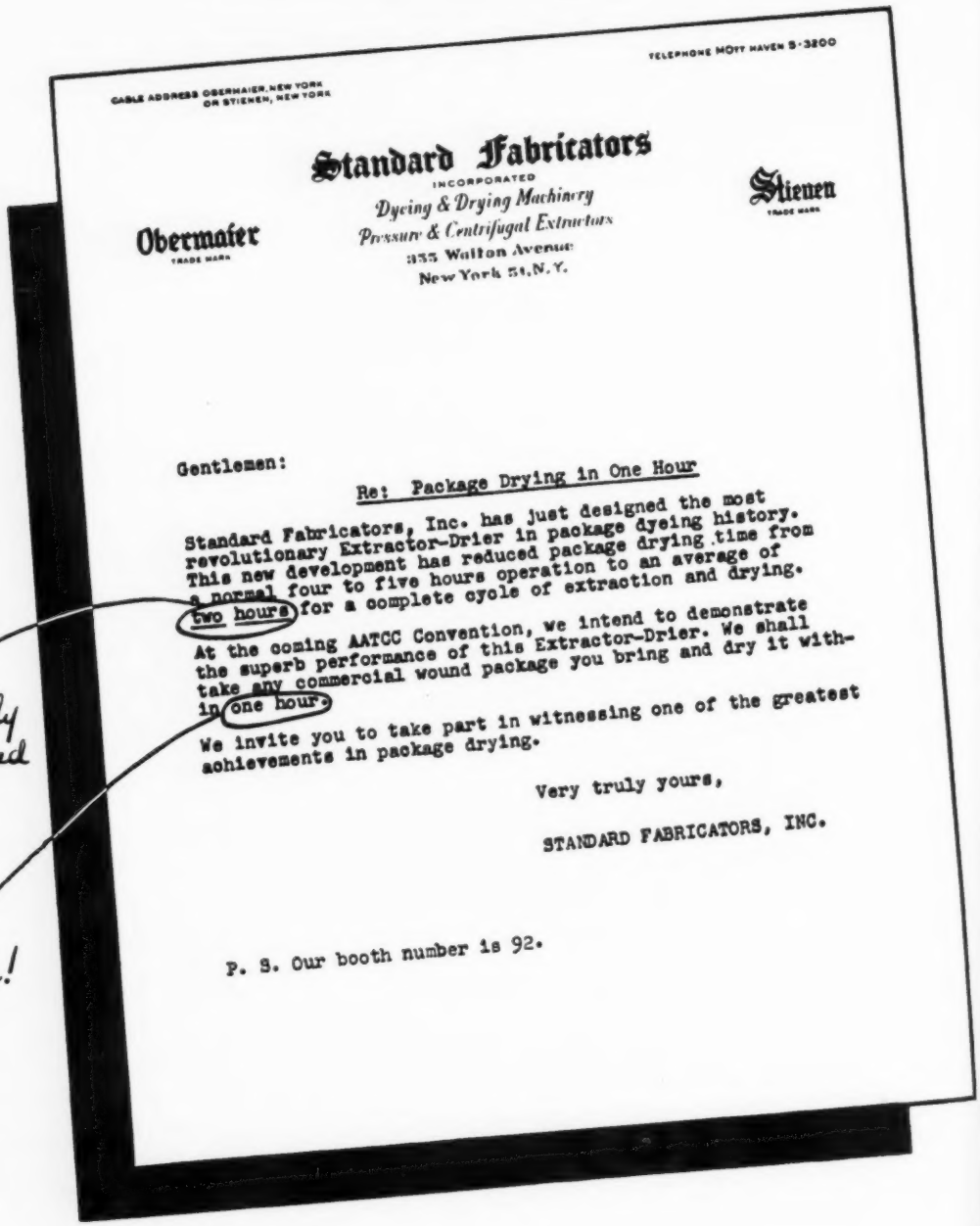

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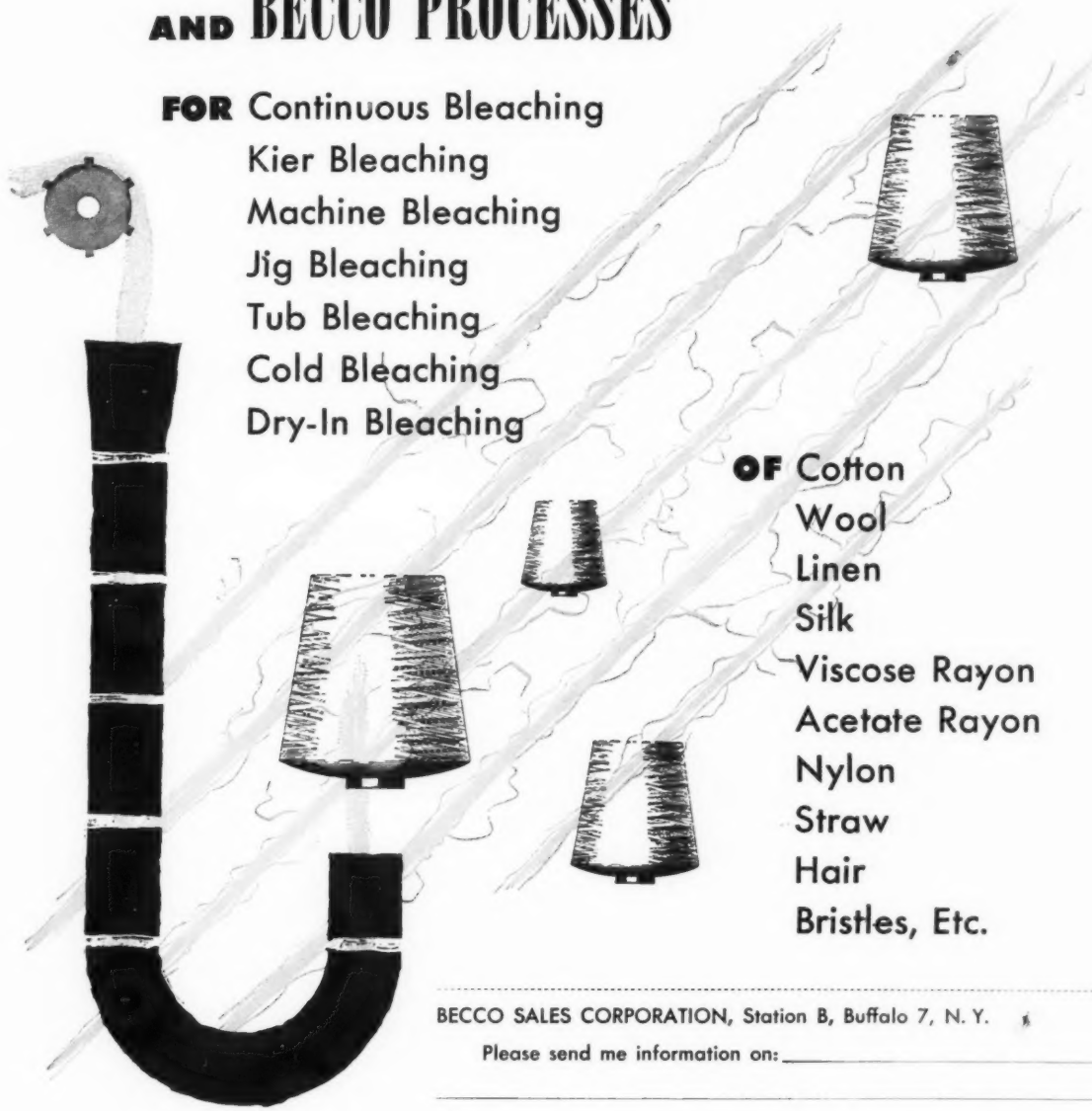

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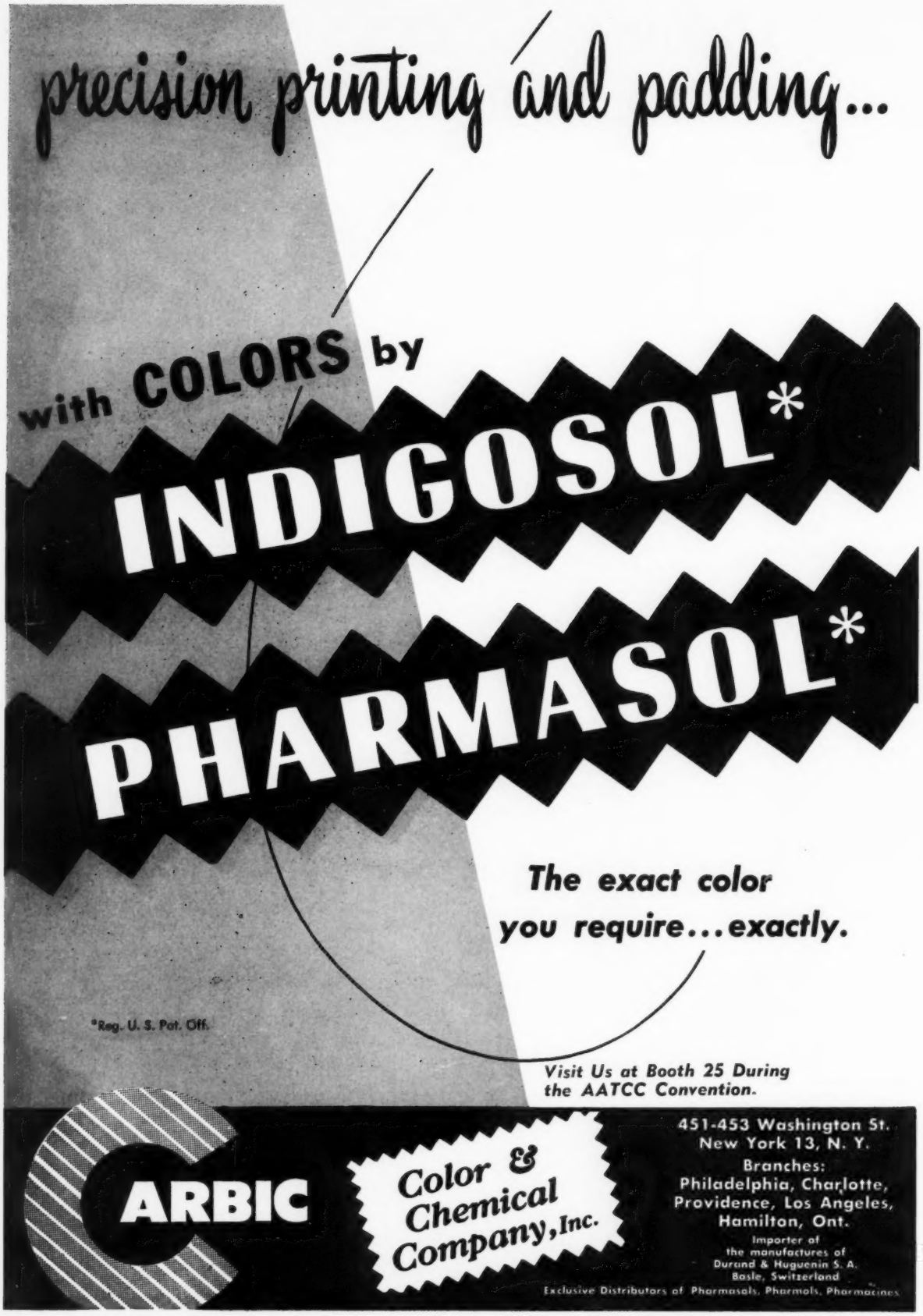
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SEPTEMBER 3, 1951
VOLUME 40 NUMBER 18

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PERCEPTIBILITY AND ACCEPTABILITY OF COLOR-CHANGES IN FASTNESS TESTS, AND "ON-TONE" FADING

I H GODLOVE
General Aniline and Film Corporation

INTRODUCTION

WHEN a dyeing fades, the average housewife or consumer, hence the dyer and colorist, is much more disturbed by change of shade (hue) than by equally perceptible changes in strength or brightness. Consequently, the *acceptability* or *rejectability* of a fading (or the tolerance in deviation from a match) is not identical with, nor necessarily proportional to, the perceptibility of the color change.

When the color of a dyeing is changed by light, washing or other destructive agency, two cases are possible: (1) the shade (hue) is changed, or (2) it remains unchanged. But the latter is rarer even in the relatively simple case where some of the dye is merely washed off; that is, when there is mere decrease in concentration. It is convenient to call the case wherein mere change of concentration occurs *"on-tone fading"*, though this may or may not involve change of hue, as will be shown. "Constant-hue fading" may include either simple loss of concentration, or the relatively rare case where change of hue due to loss of concentration is compensated by opposite change due to, say, the action of light.

In meetings of certain committees of the American Association of Textile Chemists and Colorists, the importance of change of shade (hue) was stressed, one committee officer going so far as to state the opinion that hue change should be evaluated, in testing procedures, to the practical exclusion of consideration of change of brightness and strength (or of Munsell chroma and "value"). It occurred to the author that the nature and degree of "on-tone" fading could be readily evaluated (approximately) for a given concentration change. This would make it much easier to understand and evaluate the changes in color which occur over and above those due to mere change of concentration.

An incidental question is whether the fastness rating of dyes depends largely on the perceptibility of the color-change, especially if hue-change is weighted heavily compared to the changes in the other two color attributes. This question has been investigated.

It will be shown that there is a range of hues for which the relative weighting attached to hue (compared to the weights attached to the other two color attributes) is quite important in deciding how acceptable the fading of a given perceptibility may be. But there is also at least a long range of hues (red-purple to violet to blue to green) where it makes little difference in what manner hue is weighted relative to the other aspects of the fading.

A further practical application of data on the change of color with concentration arises from the fact that they enable one to make more quantitative the qualitative theory of the changes of color with change in particle size, a theory which was presented by the author in 1940 (*1*).

In order to calculate the total amount of fading from spectrophotometric measurements on the original and "faded" dyeings, a new color-difference formula was derived and applied. This formula enables one to compute very simply the *total* or composite "fading", or color-change due to loss of concentration, from the changes in Munsell hue, chroma and "value". The latter are first evaluated from spectrophotometric reflectance readings. The formula can of course be applied to measuring any other type of fading or color-change. A paper on the derivation and practical testing of the validity of the formula, along with a condensation of the present paper on perceptibility, acceptability, and on-tone fading, has been presented almost simultaneously to the *Journal of the Optical Society of America*, under the title: "An Improved Color-difference Formula, with Applications to the Perceptibility and Acceptability of Fadings". That paper stresses the derivation, validity and applicability of the color-difference formula (or "fading index"), while the present paper takes the formula for granted and deals primarily with the subjects expressed in our present title. It will be shown that the need for a new formula arose from the obvious inability of the formulas previously in use to correctly evaluate the color differences seen by the average eye under the conditions usually holding when fadings are judged.

METHOD

The general method applied by the author was to measure the colors of two or more concentrations of a large number of commercial dyes dyed on wool or cotton (as well as of mixtures), and to plot the hue change and the total color change ("fading"), each as a function of hue. For example, the hue change and the total color change are plotted for change of concentration of many dyes from 2% to 0.5%. For the purposes of this paper, the total color change will be called the *"perceptibility"* of the change, while the hypothetical change occurring when the hue is weighted by an arbitrary constant factor (such as five times) will be called the *"acceptability"* or its negative, *"rejectability"*. It will be shown that these quantities all depend primarily on the hue of the original dyeing.

This general method was applied, in a recent paper by the present author (2) to the change of color with illumination ("the

artificial-light problem"). It was shown that this change, too, is primarily a function of the starting (daylight) hue. There is of course some scatter or deviation of individual dye points from the smoothed curves for many dyes, due to varying shapes of spectral-reflection curves which yield the same color to the eye (metameric colors). But by getting data for a large number of dyes it has been found that the hue change, "perceptibility" and "acceptability" of an on-tone fading can be predicted from the original hue alone with considerable probability. From a knowledge of the spectral-curve shapes, the direction of deviations from the curves shown here can also be predicted.

In this work commercial rather than purified dyes were used because data was needed for commercial use and because it was more economical in time to accumulate data on a large number of commercial dyeings, already prepared for other purposes, than to purify even a small number of dyes. Both wool and cotton dyes, as well as mixtures of wool dyes, were used. There is no theoretical reason why a distinction need be made between wool and cotton dyeings; but because of better "exhausts" of the dyebath of wool dyes, the nominal concentrations are closer to the actual concentrations. In general, all three types of dyeings give points plotting close to the average curve determined for all of them.

Table I (Column 8) and Figure 1 give the hue change as a function of the hue of a 2% dyeing for a change of concentration from 2% to 0.5%. The data are corrected to a constant Munsell chroma of ten by multiplying by 0.1 the chroma of the 2% dyeing. This is equivalent to assuming that the perceptibility of a given hue-change is proportional to the chroma, a plausible assumption that has been widely made. The color notations are Munsell "re-notations" obtained through spectrophotometry with the Hardy-G E Recording Spectrophotometer (3), the GAF-Librascope Tristimulus Integrator (4) and graphs for converting I C I trilinear coordinates to Munsell Renotations (5). An increase in Munsell hue number was considered positive and a decrease negative. The order of hue is that traditional in the dye industry, beginning with greenish yellow, that is, the order of hues due to an absorption band moving across the visible spectrum from the ultraviolet.

It may be seen in Figures 2, 3 and 4 that there are six points of zero change, that they are largest in the red-orange-yellow region, and not very large elsewhere. Maximum changes occur at Munsell 2R and 8YR, with zero change between (at 8R). The points which deviate most from the curves are in general colors of low chroma, so that if allowance were made for this fact less scatter would be present, and the hue change due to concentration change could be predicted with a high probability. The positions of the salient points in this curve are confirmed by the hue component of a total color-difference, calculated by the new color-difference or fading-index formula.

A similar curve was obtained for chroma change as a function of hue (Table I, Column 6). This was not reproduced here since there are no points of special interest except that three points of zero change coincide with three of the six points of zero hue change. Concerning Munsell value change with concentration change, it may be said that this is rather constant for a given hue range, being small for yellows and large for blues. The significance of this will be discussed later.

Table I contains data for 166 color changes from 2% to 0.5% concentration (weight of dye on the fiber). Similar data were also obtained for many other dyes changing from 3% to 0.5% and for a smaller number changing from 1.5% to 0.5% concentration.

THE NEW COLOR-DIFFERENCE FORMULA

The new formula for color-difference (a "fading-index" or index of deviation from match) was derived in 1945, but was not published until very recently (6) because it was previously believed that some of the existing formulas, including those involving Munsell specifications of the colors, were sufficiently satisfactory. But recently it was noticed that one of the best of these, the Balinkin formula (7), reduced to the new one (thought "correct") only if the hue and chroma changes approached zero, that is, if the color differences were very small; in the present work (and of course in practice) some larger fadings were involved. Further, both this formula and the Nickerson Index of Fading (8) proved quite inadequate to show the proper relative magnitudes of the color changes of yellows as compared to blues produced by constant concentration change. This fact

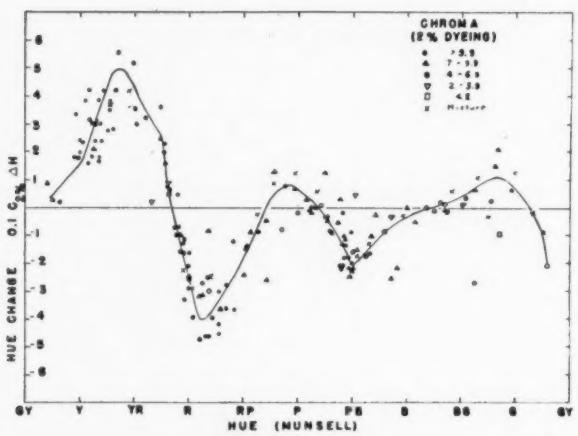

Figure 1

Hue Change as a Function of Original Hue of the 2% Dyeing, When Changing to 0.5%.

Here the "perceptibility" is assumed proportional to chroma, with chroma 10 taken as standard chroma, so that weighting of Munsell hue change is by one-tenth the original chroma. The positive direction was taken as an increase in Munsell hue number (as red to yellow); a decrease was taken as negative. The Munsell hue is indicated by initials for the hue names, e g, GY for green-yellow. The hue order is that traditional in the textile industry, the order of hues obtained from an absorption band moving from the ultraviolet across the visible spectrum. The chroma legend is given above. Note that many of the large deviations from the "best" curve are for low chromas.

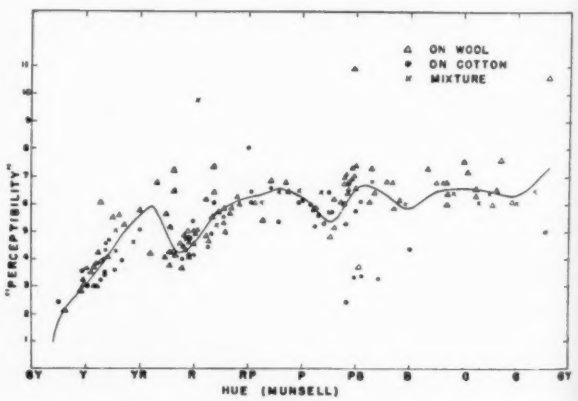

Figure 2

The Total Color Change or "Perceptibility" is a Function of Original Hue of the 2% Dyeing, when Changing to 0.5%.

Whether the dyeing is of single dyes on wool or cotton or of a mixture on wool is indicated in the legend above. The hue scale is as indicated under Figure 1. The magnitudes of the perceptibility I4 are taken from column 11 of Table I.

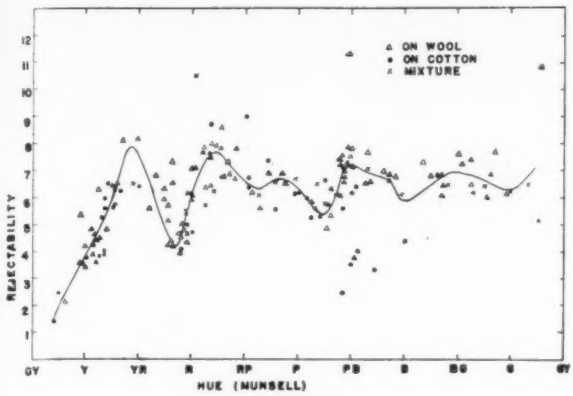

Figure 3

Rejectability as a Function of Original Hue of the 2% Dyeing, when changing to 0.5%.

The remarks on hue are the same as those of Figures 1 and 3. Wool, cotton or mixture dyeings are indicated as in Figure 3. The "rejectability", or negative aspect of "acceptability", depends upon weighting by 5 the hue component of the total color change, and is taken from column 12 of Table I.

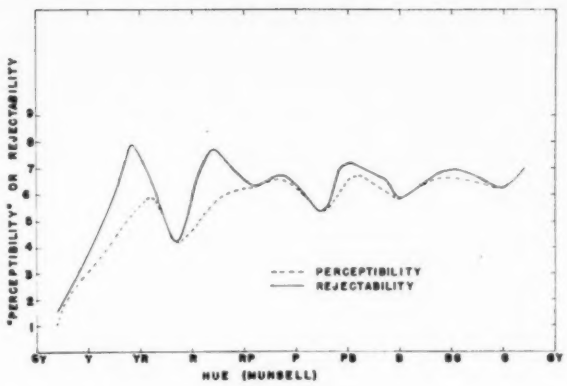

Figure 4

"Perceptibility" and Rejectability of the 2% Dyeing "Ontone" Fadings, Taken from Figures 3 and 4 and Repeated Here.

Note that the arbitrary weighting of hue by a factor of 5 has considerably altered the computed color-change or fading only in narrow hue ranges at the left of the diagram. See the text for comments on the hue ranges involved.

INDEX OF DYESTUFFS IN TABLE I

All of 2% and 0.5% concentration (relative to weight of fiber), except in the case of mixtures, where the percentages making up the total of 2% in the heavier dyeing, are given.

W32-33	Palatine Fast Violet 3RNA
W38-39	Palatine Fast Yellow GRNA
W40-41	Palatine Fast Yellow ELNA
W44-45	Milling Yellow H5GA-CF
W46-47	Supramine Yellow 3GLA-CF
W52-53	Wool Fast Orange GA-CF
W60-61	Palatine Fast Marine Blue RENA
W75-76	Diamond Red ECB Ex Conc
W85-86	Acid Anthracene Brown KE
W100	Fast Red A (see W345)
W112	Patent Blue VF Ex Conc (see W346)
W345	Fast Red A (see W100)
W346	Patent Blue VF Ex Conc (see W112)
C415-6	Direct Fast Orange MR Conc
M449	1% Carmoisine BA Ex Conc and 1% Alizarine Supra Sky RA (see M464)
W462	Alizarine Supra Sky RA (see W604)
M464	Like M449 but totalling 0.5%
W505-506	Alizarine Supra Blue A
W507-508	Alizarine Direct Blue ARA
W509-510	Naphthol Green B
W511-512	Supramine Yellow 3GL-CF
W513-514	Sulphone Yellow RS Ex
W515-516	Fast Light Orange GA Conc
W517-518	Acid Orange XX
W519-520	Acid Anthracene Red GD Ex
W523-524	Fast Light Red 4BA
W527-528	Fast Red PAT
W529-530	Anthraquinone Violet D
W531-532	Alizarine Sky Blue B
W533-534	Alizarine Cyanine Green GHN Ex
M536	1.5% Supramine Yellow 3GLA + 0.5% Fast Light Orange GA, (see M771)
W551-552	Supranol Blue GG
W553-554	Supramine Yellow GGA
W555-556	Supranol Red RA
W561-562	Milling Yellow O
W565-566	Cloth Red BN High Conc
W567-568	Wool Green BSNA
W569-570	Neptune Green SGXA
W571-572	Guinea Green BA Ex Conc
W573-574	Napthaline Green V Ex Conc
W575-576	Azo Fuchsine GA
W577-578	Supramine Red 3BA
W579-580	Supra Light Rubine BLA
W583-584	Alizarine Blue SAP
W585-586	Alizarine Direct Blue AGG
W587-588	Fast Light Yellow 3G New
W588-589	Fast Light Yellow D3GA
W591-592	Tartrazine C Ex
W593-594	Scarlet RRA New
W595-596	Alizarine Rubinol 3G
W604	Alizarine Supra Sky RA (see W462)
W606-607	Formyl Violet S3BA
W608-609	Brilliant Wool Blue FFRS
W610-611	Brilliant Milling Blue B New
W614-615	Acid Violet 6BNOO
W630-631	Alizarine Geranol B
W632-633	Alizarine Cyanine Green 5G
W644-645	Anthraquinone Green GG
M648	Like M778 but totalling 0.5%
W675-676	Alkali Fast Green 10GA
W681	Like M783 but totalling 0.5%
W691-692	Azo Phloxine GA Ex Conc
W693-694	Alizarine Rubinol GW
W699-700	Wool Fast Blue BLA Ex
C701-702	Diamine Scarlet BA
W705-706	Supramine Yellow RA
W709-710	Victoria Fast Violet RRN
W711-712	Indigotine B Ex Conc
W713-714	Patent Blue
W715-716	Supranol Yellow RA
W728-729	Sulphon Orange GA
W730-731	Anthraquinone Violet 3RA
W732-733	Wool Fast Blue GLA
M751	Like M775 but totalling 0.5%
M771	1.5% Supramine Yellow 3GLA and 0.5% Fast Light Orange GA
M775	1.6% Supramine Yellow 3GLA and 0.4% Napthaline Green V Ex Conc
M778	1% Napthaline Green V Ex Conc and 1% Alizarine Supra Sky RA
M783	1% Anthraquinone Violet 4BF and 1% Alizarine Rubinol R
C1020-1021	Fastusol Yellow GGA-CF
C1022-1923	Fastusol Yellow L5GA
C1024-1025	Fastusol Yellow GA Ex
C1030-1031	Fastusol Yellow LRTF Ex Conc CF
C1032-1033	Stilbene Yellow 5GXT-Ex CF
C1036-1037	Stilbene Yellow TP Conc
C1038-1039	Chrysophenine YA Supra Conc CF
C1086-1087	Diamine Scarlet BA-CF
C1088-1089	Diamine Scarlet 3BA-CF

TABLE I

"ON-TONE FADING" (CONCENTRATION CHANGE ONLY) 2% → 0.5%

In each pair, the upper figures refer to the 0.5% dyeing, the lower figures to the 2% dyeing or to the pair together. In column 1, C refers to cotton, W refers to wool and M to a mixture.

Ser No	H	C	V	ΔH	ΔC	ΔV	0.1 $C_t\Delta H$	δH	5δH	I_t	J_t	I_n
C 1022	2.0GY	8.1	9.3									
C 1023	1.0GY	8.7	9.2	+1.0	0.6	0.1	+0.87	0.28	1.40	0.89	1.39	5.9
C 369	0.4GY	7.2	9.15									
C 370	0.1GY	9.4	8.9	+0.3	2.2	0.25	+0.28	0.027	0.13	2.42	2.44	9.2
W 44	9.0Y	8.6	8.1									
W 45	8.8Y	10.3	7.8	+0.2	1.7	0.3	+0.21	0.018	0.09	2.09	2.10	7.7
W 587	7.5Y	10.2	8.3									
W 588	6.0Y	12.7	8.1	+1.5	2.5	0.2	+1.91	1.14	5.70	2.83	3.55	16.3
C 1020	9.0Y	9.5	8.7									
C 1021	5.8Y	10.4	8.0	+3.2	0.9	0.7	+3.33	3.97	19.85	3.55	5.34	20.2
W 46	7.0Y	8.9	8.1									
W 47	5.5Y	11.8	7.8	+1.5	2.9	0.3	+1.77	0.56	2.80	3.23	3.56	17.8
W 463	7.0Y	8.6	8.2									
W 454	5.0Y	12.0	8.0	+2.0	3.4	0.2	+2.40	1.04	5.20	3.64	4.17	21.0
W 589	6.5Y	10.3	8.3									
W 590	5.0Y	13.1	8.1	+1.5	2.8	0.2	+1.95	0.59	2.95	3.01	3.38	17.5
C 1024	7.0Y	9.3	8.5									
C 1025	4.8Y	10.7	7.9	+2.2	1.4	0.6	+2.35	1.28	6.40	3.00	3.76	17.2
W 511	7.2Y	9.0	8.3									
W 512	4.0Y	12.0	8.1	+3.2	3.0	0.2	+3.84	2.70	13.50	3.51	4.81	25.6
W 553	5.0Y	8.3	7.9									
W 554	3.6Y	11.0	7.3	+1.4	2.7	0.6	+1.54	2.25	0.45	3.68	3.91	17.9
W 673	6.5Y	12.0	8.2									
W 674	3.5Y	14.0	7.8	+3.0	2.0	0.4	+4.20	2.26	11.30	2.97	4.23	25.2
W 705	5.8Y	8.8	8.2									
W 706	3.2Y	12.0	7.8	+2.6	3.2	0.4	+3.12	1.70	8.50	3.81	4.62	24.5
W 591	5.0Y	12.6	8.1									
W 592	3.0Y	14.9	7.7	+2.0	2.3	0.4	+2.98	0.99	4.95	2.97	3.58	19.2
W 40	4.5Y	8.5	5.6									
W 41	2.8Y	10.6	6.7	+1.7	2.1	0.9	+1.80	0.43	2.15	4.22	4.42	18.9
W 67	4.8Y	8.9	6.6									
W 68	2.5Y	9.1	5.1	+2.3	0.2	1.5	+2.09	0.70	3.50	6.06	6.29	18.0
W 513	4.5Y	10.1	8.1									
W 514	2.3Y	13.5	7.7	+2.2	3.4	0.4	+2.97	1.18	5.90	3.91	4.48	24.5
C 1032	4.2Y	10.0	8.8									
C 1033	2.3Y	12.3	8.3	+1.9	2.3	0.5	+2.34	1.04	5.20	3.21	3.81	19.2
C 1026	4.8Y	8.8	8.5									
C 1027	2.0Y	11.0	7.8	+2.8	2.2	0.7	+3.08	2.98	14.90	3.95	5.25	23.1
C 1643	4.4Y	9.9	8.6									
C 1644	1.5Y	13.1	8.1	+2.9	3.2	0.5	+3.80	4.28	21.40	4.30	5.97	27.8
C 1028	3.2Y	7.9	8.1									
C 1029	1.5Y	9.6	7.4	+1.7	1.7	0.7	+1.63	4.30	0.86	3.40	3.88	15.8
C 1030	3.2Y	8.6	8.3									
C 1031	1.5Y	10.4	7.6	+1.7	1.8	0.7	+1.77	1.02	5.10	3.48	4.02	16.7
C 353	4.0Y	8.3	8.4									
C 354	1.3Y	11.1	7.6	+2.7	2.8	0.8	+3.00	2.65	13.25	4.55	5.60	25.2
W 561	3.0Y	9.2	8.0									
W 562	1.1Y	12.5	7.5	+1.9	3.3	0.5	+2.37	1.63	8.15	4.06	4.80	22.4
C 1645	3.8Y	10.6	8.6									
C 1646	0.8Y	13.6	7.9	+3.0	3.0	0.7	+4.08	5.10	25.50	4.68	6.51	29.5
W 69	2.7Y	9.1	6.7									
W 70	10.0YR	10.1	5.4	+2.7	1.0	1.3	+2.73	2.65	13.20	5.54	6.43	21.7
C 1038	2.5Y	11.5	8.3									
C 1039	9.7YR	13.5	7.8	+2.8	2.0	0.5	+3.78	4.78	23.90	3.58	5.65	24.1
C 1034	2.5Y	9.0	8.5									
C 1035	9.6YR	12.0	7.9	+2.9	3.0	0.6	+3.48	3.56	17.80	4.28	5.71	26.5
M 772	2.1Y	9.8	7.9									
M 620	9.5YR	14.0	7.4	+2.6	4.2	0.5	+3.64	3.65	18.25	5.03	6.32	30.2
W 38	1.5Y	9.9	7.0									
W 39	9.0YR	11.2	5.7	+2.5	1.3	1.3	+2.80	2.73	13.65	5.61	6.51	22.9
C 1036	1.8Y	10.7	8.3									
C 1037	8.5YR	12.7	7.7	+3.3	2.0	0.6	+4.19	5.82	29.10	3.95	6.23	26.4
W 715	2.1Y	10.7	7.5									
W 716	8.0YR	13.5	6.7	+4.1	2.8	0.8	+5.54	9.53	47.65	5.25	8.11	35.3
M 771	9.1YR	11.1	7.5									
M 536	6.2YR	14.3	6.9	+2.9	3.2	0.6	+4.15	5.24	26.20	4.61	6.50	29.8
W 52	9.0YR	10.7	6.9									
W 53	5.2YR	13.7	5.9	+3.8	3.0	1.0	+5.21	8.33	41.65	5.78	8.17	35.8
C 415	7.9YR	10.1	7.5									
C 416	5.1YR	12.5	6.5	+2.8	2.4	1.0	+3.50	3.89	19.45	5.06	6.42	30.2
W 515	5.0YR	13.5	7.0									
W 516	3.0YR	16.0	6.3	+2.0	2.5	0.7	+3.20	3.41	17.05	4.18	5.58	24.5
W 612	2.6YR	2.7	4.0									
W 613	1.9YR	2.5	2.3	+0.7	0.2	1.7	+0.18	0.014	0.07	6.80	6.81	11.5
W 517	2.5YR	14.9	6.4									
W 518	0.3YR	16.2	5.6	+2.2	1.3	0.8	+3.57	4.59	22.95	4.06	5.91	23.0
W 71	2.5YR	8.8	5.0									
W 72	0.2YR	10.6	3.7	+2.3	1.8	1.3	+2.44	1.94	9.70	5.67	6.32	23.0
W 549	1.0YR	12.4	5.9									
W 550	9.6R	13.9	4.7	+1.4	1.5	1.2	+1.95	1.34	6.70	5.16	5.66	19.5

TABLE I (continued)

Ser	No	H	C	V	ΔH	ΔC	ΔV	0.1 $C_1\Delta H$	δH	5δH	I_1	J_1	I_n
W	728	1.1YR	15.1	6.0									
W	729	9.6R	15.1	5.0	+1.5	0.0	1.0	+2.26	2.01	10.05	4.24	5.11	15.1
W	636	0.5YR	15.0	5.9									
W	637	9.5YR	15.5	5.0	+1.0	0.5	0.9	+1.55	0.93	4.65	3.76	4.23	13.1
W	695	9.5R	12.5	6.1									
W	696	9.0R	14.7	5.2	+0.5	2.2	0.9	+0.74	0.18	0.90	4.24	4.33	14.9
W	64	2.5YR	2.1	4.3									
W	65	8.8R	2.5	2.5	+3.5	0.4	1.8	+0.87	0.25	1.25	7.23	7.30	15.5
W	85	1.8YR	2.6	3.3									
W	86	8.8R	1.7	1.7	+3.0	0.9	1.6	+0.51	0.16	0.80	6.47	6.52	14.3
W	519	8.9R	14.5	5.6									
W	529	8.5R	15.5	4.6	+0.4	1.0	1.0	+0.62	0.13	0.65	4.14	4.20	11.5
W	593	7.1R	13.9	5.6									
W	594	7.6R	15.0	4.5	−0.5	1.1	1.1	−0.75	0.21	1.05	4.56	4.65	12.9
W	789	6.6R	14.9	4.7									
W	539	7.3R	14.7	3.8	−0.7	0.2	0.9	−1.03	0.44	2.20	3.66	3.90	10.1
C	701	7.5R	14.2	4.9									
C	702	7.2R	14.5	3.9	+0.3	0.3	1.0	+0.44	0.41	0.082	4.02	4.06	8.6
W	697	6.5R	13.6	5.2									
W	698	7.0R	14.2	4.1	−0.5	0.6	1.1	−0.71	0.19	0.95	4.46	4.55	11.2
W	73	5.8R	10.1	4.3									
W	74	6.8R	9.9	3.1	−1.0	0.2	1.2	−0.99	0.40	2.00	4.85	5.01	11.8
W	525	5.4R	14.6	4.5									
W	526	6.6R	13.4	3.5	−1.2	1.2	1.0	−1.61	1.10	5.50	4.31	4.79	16.0
W	555	5.0R	13.1	5.1									
W	556	6.2R	14.2	3.9	−1.2	1.1	1.2	−1.70	1.04	5.20	5.03	5.43	17.3
M	466	4.3R	11.8	4.7									
M	451	6.1R	12.7	3.6	−1.8	0.9	1.1	−2.29	1.92	9.60	4.70	5.46	18.4
C	703	4.9R	13.0	4.3									
C	704	6.0R	11.6	3.2	−1.1	1.4	1.1	−1.28	0.72	3.60	4.70	4.99	15.7
W	557	5.0R	13.2	4.6									
W	558	5.9R	13.0	3.6	−0.9	0.2	1.0	−1.17	0.55	2.75	4.08	4.34	11.3
W	345	4.5R	11.4	4.1									
W	100	5.9R	11.7	3.1	−1.4	0.3	1.0	−1.64	1.04	5.20	4.14	4.62	13.5
W	689	3.5R	13.8	5.1									
W	690	5.8R	14.5	4.1	−2.3	0.7	1.0	−3.33	4.16	20.80	4.64	6.17	21.4
C	563	3.2R	12.7	4.2									
C	564	5.2R	10.7	3.0	−2.0	2.0	1.2	−2.14	2.15	10.75	5.41	6.15	21.8
W	461	2.6R	12.8	4.2									
W	452	5.1R	11.9	3.2	−2.5	0.9	1.0	−2.97	3.75	18.70	4.54	5.96	20.6
W	565	1.0R	11.0	3.2									
W	566	5.1R	8.6	2.3	−4.1	2.4	0.9	−3.52	6.24	31.20	5.00	7.07	26.7
C	1086	3.5R	12.7	5.3									
C	1087	5.0R	11.0	4.4	−1.5	1.7	0.9	−1.65	1.23	6.15	4.13	4.69	17.8
W	461	2.6R	12.8	4.2									
W	101	4.9R	11.3	3.1	−2.3	1.5	1.1	−2.60	3.01	15.05	4.96	6.05	21.5
M	788	2.3R	15.9	6.2									
M	493	4.5R	13.3	3.9	−2.2	2.6	2.3	−2.93	4.02	20.10	9.77	10.56	33.3
W	691	1.5R	14.0	5.0									
W	692	4.3R	14.2	3.9	−2.8	0.2	1.1	−3.98	6.13	30.65	5.06	7.08	23.1
W	527	9.5RP	11.6	4.0									
W	528	3.0R	9.2	2.7	−3.5	2.4	1.3	−3.22	5.14	25.70	6.17	7.65	27.9
W	577	9.3RP	14.5	4.5									
W	578	2.8R	13.6	3.6	−3.5	0.9	0.9	−4.76	9.50	47.50	4.83	7.83	27.1
W	559	9.2RP	10.6	3.7									
W	560	2.6R	9.4	2.7	−3.4	1.2	1.0	−3.19	4.53	22.65	4.69	6.34	22.4
C	1088	10.0RP	11.8	4.8									
C	1089	2.5R	11.1	3.8	−2.5	0.7	1.0	−2.77	3.22	16.10	4.44	5.71	19.2
C	1090	8.0RP	12.0	4.9									
C	1091	1.8R	12.2	3.9	−3.8	0.2	1.0	−4.64	8.31	41.55	4.94	7.59	25.1
W	595	9.5RP	11.7	5.8									
W	596	1.6R	12.7	4.5	−2.1	1.0	1.3	−2.56	2.58	12.90	5.54	6.40	21.5
C	411	7.6RP	12.6	5.2									
C	412	1.6R	12.2	3.9	−4.0	0.4	1.3	−4.64	9.65	48.30	6.07	8.69	28.5
W	75	0.5R	12.8	4.2									
W	76	1.5R	8.6	2.7	−1.0	4.2	1.5	−0.86	0.44	2.20	7.36	7.48	25.0
W	543	6.4RP	9.1	3.4									
W	544	1.4R	6.1	2.1	−5.0	3.0	1.3	−3.05	5.43	27.15	6.45	7.96	29.0
M	787	9.0RP	11.4	5.2									
M	623	1.0R	12.6	4.0	−2.0	1.2	1.2	−2.52	2.87	14.35	5.23	6.23	20.9
W	523	6.6RP	11.9	4.0									
W	524	0.5R	10.3	2.8	−3.9	1.6	1.2	−4.02	7.33	36.65	5.74	7.89	28.1
W	547	6.0RP	13.7	4.1									
W	548	9.6RP	11.7	3.1	−3.6	2.0	1.0	−4.21	8.18	40.90	5.31	7.81	28.0
C	1094	6.8RP	11.3	5.2									
C	1095	9.5RP	11.3	3.9	−2.7	0.0	1.3	−3.05	3.68	18.40	5.54	6.75	20.8
W	638	5.6RP	14.0	4.3									
W	639	9.5RP	11.7	3.2	−3.9	2.3	1.1	−4.56	9.80	49.00	5.87	8.58	31.8
W	521	5.3RP	9.2	3.7									
W	522	9.2RP	9.5	2.6	−3.9	0.3	1.1	−3.70	5.23	26.15	4.97	6.76	22.3
W	575	5.2RP	11.9	4.6									
W	576	8.3RP	11.8	3.3	−3.1	0.1	1.3	−3.66	5.31	26.55	5.69	7.32	22.7
W	579	5.6RP	10.8	4.7									
W	580	8.1RP	11.3	3.3	−2.5	0.5	1.4	−2.82	3.00	15.00	5.89	6.83	21.2

TABLE I (continued)

Ser No	H	C	V	ΔH	ΔC	ΔV	0.1 $C_2\Delta H$	δH	5δH	I_4	J_4	I_n
W 693	6.0RP	11.1	5.8									
W 694	7.0RP	12.6	4.3	−1.0	1.5	1.5	−1.26	1.23	6.15	6.29	6.67	21.1
W 800	3.8RP	14.5	5.5									
W 624	6.7RP	12.8	4.2	−2.9	1.7	1.3	−3.71	6.13	30.65	6.01	7.79	27.7
C 1092	2.0RP	14.0	4.5									
C 1093	5.0RP	8.2	3.2	−3.0	5.8	1.3	−2.46	4.06	20.30	8.05	9.00	35.0
C 419	3.1RP	10.4	5.75									
C 420	4.5RP	10.5	4.25	−1.4	0.1	1.5	−1.47	0.85	4.25	6.07	6.35	15.2
C 1673	3.0RP	10.4	5.7									
C 1674	4.4RP	9.9	4.1	−1.4	0.5	1.6	−1.39	0.80	4.00	6.48	6.73	16.6
W 730	2.7RP	8.7	4.0									
W 731	3.8RP	8.1	2.5	−1.1	0.6	1.5	−0.89	0.34	1.70	6.06	6.17	14.3
M 464	1.6RP	5.1	3.2									
M 449	2.6RP	2.8	1.8	−1.0	2.3	1.4	−0.28	0.057	0.28	6.06	6.07	16.4
W 640	1.4RP	11.8	4.5									
W 641	2.3RP	10.3	3.2	−0.9	1.5	1.3	−0.93	0.39	1.95	5.45	5.59	16.0
W 529	0.1RP	8.0	4.0									
W 530	0.8RP	7.3	2.3	−0.7	0.7	1.7	−0.51	0.12	0.60	6.84	6.88	14.3
C 1109	8.1P	9.0	5.6									
C 1108	0.8RP	9.7	4.0	−2.7	0.7	1.6	−2.62	2.51	12.55	6.63	7.35	22.2
M 785	0.4RP	7.9	4.8									
M 683	9.4P	8.6	3.2	+1.0	0.7	1.6	+0.86	0.27	1.35	6.46	6.54	15.1
C 1106	8.0P	6.7	4.5									
C 1107	9.4P	9.0	3.3	−1.4	2.3	1.2	+1.26	0.47	2.35	5.37	5.54	19.1
W 32	6.5P	5.0	4.0									
W 33	8.0P	5.3	2.3	−1.5	0.3	1.7	−0.80	0.23	1.15	6.82	6.89	14.3
W 630	8.3P	8.1	5.4									
W 631	7.6P	10.5	3.9	+0.7	2.4	1.5	+0.74	0.16	0.80	6.48	6.53	19.1
C 1174	4.9P	9.5	4.9									
C 1175	5.7P	8.6	3.4	−0.8	0.9	1.5	−0.69	0.21	1.05	6.09	6.16	14.5
M 784	6.9P	7.7	4.6									
M 682	5.5P	8.6	3.0	+1.4	0.9	1.6	+1.20	0.52	2.60	6.51	6.66	17.1
C 1170	4.7P	9.4	4.4									
C 1171	5.0P	6 8	3.0	−0.3	2.6	1.4	−0.20	0.03	0.15	6.17	6.19	17.0
C 1158	3.8P	7.9	4.8									
C 1159	3.4P	7.8	3.3	+0.4	0.1	1.5	+0.31	0.04	0.20	6.01	6.02	10.5
C 1160	2.7P	9.6	4.4									
C 1161	2.8P	8.0	3.0	−0.1	1.6	1.4	−0.08	0.00	0.00	5.82	5.82	13.5
C 385	2.4P	9.5	4.5									
C 386	2.6P	9.2	3.2	−0.2	0.3	1.3	−0.18	0.02	0.10	5.21	5.22	9.4
W 709	2.5P	6.3	3.2									
W 710	2.5P	4.5	1.8	0.0	1.8	1.4	0.00	0.00	0.00	5.88	5.88	13.8
C 1172	2.0P	9.4	4.4									
C 1173	2.0P	7.3	3.1	0.0	2.1	1.3	0.00	0.00	0.00	5.61	5.61	14.1
M 783	2.1P	8.4	4.2									
M 681	1.5P	9.2	2.6	+0.6	0.8	1.6	+0.56	0.11	0.55	6.46	6.49	14.2
C 1162	1.0P	7.0	4.4									
C 1163	0.9P	6.0	3.1	+0.1	1.0	1.3	+0.06	0.00	0.00	5.30	5.30	11.0
C 77	1.5P	7.4	3.3									
C 78	10.0PB	8.0	1.7	+1.5	0.6	1.6	+1.20	0.52	2.60	6.47	6.63	16.2
M 782	9.6PB	8.9	4.0									
M 684	10.0PB	10.1	2.6	−0.4	1.2	1.4	−0.40	0.05	0.25	5.73	5.75	13.6
W 606	9.4PB	11.3	3.3									
W 607	9.7PB	11.7	2.1	−0.3	0.4	1.2	−0.35	0.05	0.25	4.82	4.84	9.8
C 1156	9.0PB	7.9	5.5									
C 1157	9.5PB	9.1	4.1	−0.5	1.2	1.4	−0.46	0.07	0.35	5.73	5.75	13.8
W 642	8.2PB	9.5	4.0									
W 643	9.0PB	11.0	2.5	−0.8	1.5	1.5	−0.88	0.27	1.35	6.21	6.30	17.0
W 614	8.0PB	11.7	2.7									
W 615	9.0PB	9.1	1.6	−1.0	2.6	1.1	−0.91	0.43	2.15	5.15	5.32	18.0
W 699	7.0PB	8.9	3.5									
W 700	7.7PB	8.0	2.0	−0.7	0.9	1.5	−0.56	0.14	0.70	6.08	6.13	13.9
W 581	7.6PB	8.4	3.6									
W 582	7.2PB	7.9	2.1	+0.4	1.5	1.5	+0.32	0.04	0.20	6.03	6.04	11.8
W 610	5.4PB	9.6	4.5									
W 611	7.2PB	12.2	2.9	−1.8	2.6	1.6	−2.20	1.50	7.50	7.02	7.43	26.2
W 608	5.3PB	9.6	4.3									
W 609	7.2PB	11.4	2.7	−1.9	1.8	1.6	−2.16	1.55	7.75	6.77	7.21	23.7
C 81	5.0PB	7.9	2.9									
C 82	6.8PB	7.4	1.6	−1.8	0.5	1.3	−1.33	0.75	3.75	5.29	5.57	14.6
W 462	4.8PB	9.0	4.4									
W 453	6.8PB	10.7	2.7	−2.0	1.7	1.7	−2.14	1.52	7.60	7.12	7.53	23.9
C 1264	6.6PB	10.0	5.0									
C 1265	6.8PB	10.4	4.4	−0.2	0.4	0.6	−0.21	0.02	0.10	2.44	2.45	5.6
W 462	4.8PB	9.0	4.4									
W 604	6.5PB	11.0	2.8	−1.7	2.0	1.6	−1.87	1.13	5.65	6.79	7.11	23.1
W 732	5.2PB	7.8	3.95									
W 733	6.5PB	8.1	2.35	−1.3	0.3	1.6	−1.05	0.42	2.10	6.44	6.57	14.7
W 531	5.0PB	8.3	4.2									
W 532	6.3PB	8.9	2.5	−1.3	0.6	1.7	−1.16	0.49	2.45	6.86	7.00	16.6
W 734	4.9PB	8.6	4.4									
W 735	6.3PB	9.8	2.8	−1.4	1.2	1.6	−1.37	0.66	3.30	6.56	6.76	18.7
W 505	4.0PB	8.7	4.3									
W 506	5.9PB	9.5	2.6	−1.9	0.8	1.7	−1.80	1.17	5.85	6.93	7.26	19.8

Ser No
W 583
W 584
W 545
W 546
W 507
W 508
C 1266
C 1267
W 628
W 629
W 634
W 635
C 1126
C 1127
W 60
W 61
C 1124
C 1125
C 383
C 384
W 551
W 552
M 780
M 650
W 711
W 712
W 585
W 586
C 1268
C 1269
W 62
W 63
W 79
W 80
W 346
W 112
W 713
W 714
M 779
M 649
C 1693
C 1694
W 567
W 568
W 736
W 737
W 533
W 534
W 20
W 21
W 569
W 570
W 83
W 84
M 778
M 648
W 59
W 59(a)
W 707
W 708
W 644
W 645
W 571
W 572
M 777
M 647
M 465
M 450
W 632
W 633
W 573
W 574
W 89
W 90
W 675
W 676
M 776
M 752
M 775
M 751
M 774
M 750
W 509
W 510

TABLE I (concluded)

Ser	No	H	C	V	ΔH	ΔC	ΔV	0.1 C_2ΔH	δH	5δH	I_4	J_4	I_n
W	583	2.5PB	7.4	4.1									
W	584	5.6PB	7.1	2.3	−3.1	0.3	1.8	−2.20	1.99	9.95	7.35	7.87	20.5
W	545	2.5PB	7.6	5.5									
W	546	5.4PB	8.6	2.8	−2.9	1.0	2.7	−2.49	2.16	10.80	10.94	11.33	29.2
W	507	2.7PB	7.1	4.8									
W	508	5.3PB	8.5	3.1	−2.6	1.4	1.7	−2.21	1.60	8.00	7.06	7.50	23.2
C	1266	4.3PB	9.2	5.1									
C	1267	5.2PB	10.0	4.3	−0.9	0.8	0.8	−0.90	0.29	1.45	3.34	3.51	10.8
W	628	2.5PB	8.0	4.8									
W	629	5.0PB	9.0	3.2	−2.5	1.0	1.6	−2.25	1.77	8.85	6.62	7.13	21.6
W	634	2.5PB	6.8	4.7									
W	635	5.0PB	8.2	2.9	−2.5	1.4	1.8	−2.05	1.37	6.85	7.43	7.79	23.2
C	1126	2.5PB	7.4	4.5									
C	1127	5.0PB	6.5	3.1	−2.5	0.9	1.4	−1.63	1.18	5.90	5.77	6.17	17.6
W	60	5.5PB	4.3	3.5									
W	61	4.5PB	3.6	2.6	+1.2	0.7	0.9	+0.43	0.09	0.45	3.68	3.73	9.2
C	1124	2.0PB	7.4	4.9									
C	1125	4.2PB	7.0	3.4	−2.2	0.4	1.5	−1.54	0.98	4.90	6.10	6.41	16.4
C	383	1.6PB	7.2	4.3									
C	384	4.0PB	7.0	3.5	−2.4	0.2	0.8	−1.68	1.14	5.70	3.38	4.00	12.1
W	551	9.9B	6.9	4.4									
W	552	2.5PB	6.7	2.9	−2.6	0.2	1.5	−1.74	1.23	6.15	6.11	6.50	16.6
M	780	10.0B	7.0	4.5									
M	650	2.0PB	6.7	2.8	−2.0	0.3	1.7	−1.34	0.74	3.70	6.86	7.07	16.5
W	711	9.2B	6.7	4.5									
W	712	2.0PB	6.0	2.7	−2.8	0.7	1.8	−1.68	1.24	6.20	7.32	7.65	19.6
W	585	10.0B	6.5	4.8									
W	586	1.5PB	7.1	3.2	−1.5	0.6	1.6	−1.06	0.41	2.05	6.46	6.58	15.7
C	1268	0.5PB	9.1	5.4									
C	1269	0.8PB	8.4	4.6	−0.3	0.7	0.8	−0.25	0.03	0.15	3.28	3.30	7.9
W	62	7.2B	4.9	3.95									
W	63	9.2B	4.4	2.25	−2.0	0.5	1.7	−0.88	0.34	1.70	6.85	6.95	15.2
W	79	6.8B	3.6	3.6									
W	80	8.0B	3.1	1.9	−1.2	0.5	1.7	−0.37	0.06	0.30	6.82	6.84	13.2
W	346	5.0B	8.1	4.7									
W	112	7.9B	8.9	3.3	−2.9	0.8	1.4	−2.58	2.38	11.90	5.86	6.63	21.1
W	713	4.0B	8.0	4.8									
W	714	6.8B	7.8	3.3	−2.8	0.2	1.5	−2.18	1.92	9.60	6.17	6.76	18.3
M	779	5.3B	6.1	4.4									
M	649	5.8B	5.5	2.9	−0.5	0.6	1.5	−0.28	0.03	0.15	6.03	6.04	11.9
C	1693	5.0B	7.1	7.5									
C	1694	5 0B	8.9	6.5	0.0	1.8	1.0	0.00	0.00	0.00	4.39	4.39	11 4
W	567	1.5B	5.9	4.3									
W	568	1.5B	4.6	2.5	0.0	1.3	1.8	0.00	0.00	0.00	7.32	7.32	14.7
W	736	9.8BG	4.4	5.0									
W	737	10.0BG	4.6	3.3	−0.2	0.2	1.7	−0.09	0.00	0.00	6.80	6.80	11.2
W	533	9.2BG	5.3	4.4									
W	534	8.8BG	4.8	2.7	+0.4	0.5	1.7	+0.19	0.02	0.10	6.81	6.82	12.5
W	20	8.5BG	5.1	4.3									
W	21	8.2BG	4.7	2.6	+0.3	0.4	1.7	+0.14	0.01	0.05	6.81	6.81	12.0
W	569	7.9BG	8.7	4.7									
W	570	8.0BG	8.0	3.2	−0.1	0.7	1.5	−0.08	0.00	0.00	6.04	6.04	11.4
W	83	7.5BG	4.8	4.2									
W	84	7.8BG	4.8	2.6	−0.3	0.0	1.6	−0.14	0.01	0.05	6.40	6.41	10.2
M	778	7.8BG	6.4	4.5									
M	648	6.8BG	5.8	2.9	+1.0	0.6	1.6	+0.58	0.75	0.15	6.44	6.48	13.7
W	59	5.0BG	3.8	4.4									
W	59(a)	4.8BG	3.8	2.5	+0.2	0.0	1.9	+0.08	0.00	0.00	7.61	7.61	11.7
W	707	5.0BG	4.4	4.6									
W	708	4.2BG	4.3	2.8	+0.8	0.1	1.8	+0.34	0.05	0.25	7.21	7.22	12.5
W	644	6.9G	4.6	5.2									
W	645	2.6BG	4.8	3.6	−5.7	0.2	1.6	−2.74	2.80	14.00	6.62	7.41	21.1
W	571	3.3BG	8.2	4.8									
W	572	2.5BG	8.1	3.2	+0.8	0.1	1.6	+0.65	0.17	0.85	6.42	6.47	12.5
M	777	3.6BG	7.3	4.5									
M	647	2.1BG	7.0	3.0	+1.5	0.3	1.5	+1.05	0.45	2.25	6.05	6.19	14.1
M	465	9.3G	4.6	5.0									
M	450	10.0G	4.8	3.4	−0.7	0.2	1.6	−0.34	0.05	0.25	6.40	6.42	11.5
W	632	10.0G	6.2	5.2									
W	633	9.6G	5.9	3.7	+0.4	0.3	1.5	+0.24	0.02	0.10	6.01	6.02	10.8
W	573	0.8BG	8.4	4.7									
W	574	8.8G	7.4	3.1	+2.0	1.0	1.6	+1.48	0.98	4.90	6.55	6.85	18.5
W	89	1.5G	1.1	4.1									
W	90	8.0G	1.5	2.2	−6.5	0.4	1.9	−0.98	0.27	1.35	7.63	7.70	16.5
W	675	6.5G	8.0	6.0									
W	676	5.8G	9.0	4.5	+0.7	1.0	1.5	+0.63	0.14	0.70	6.10	6.14	14.5
M	776	6.6G	9.0	5.0									
M	752	5.2G	8.9	3.5	+1.4	0.1	1.5	+1.25	0.62	3.10	6.05	6.26	14.3
M	775	1.6G	9.0	6.2									
M	751	1.8G	10.1	4.6	−0.2	1.1	1.6	−0.20	0.02	0.10	6.50	6.51	13.7
M	774	8.9GY	9.0	6.8									
M	750	9.8GY	10.4	5.6	−0.9	1.4	1.2	−0.94	0.30	1.50	5.03	5.15	15.1
W	509	5.0GY	3.0	6.7									
W	510	9.2GY	5.0	4.1	−4.2	2.0	2.6	−2.10	1.04	5.20	10.64	10.83	30.0

will be elaborated upon after indication of the method of use of the new formula, which apparently gives much more nearly the proper relation. A third reason for using the new formula is that it can be derived (*6*) in a remarkably simple way from the single assumption that the color change can be represented by the length of a straight line in ordinary Euclidean space used as the "color space" in which the colors are plotted.

It may be stated here that the formula is much simpler in use than it appears at first glance. The final formula (*6*) is as follows:

$$I_4 = \left\{2C_1C_2\Phi(H) + (\Delta C)^2 + (4\Delta V)^2\right\}^{1/2} \quad (1)$$

$$\text{where} \qquad \Phi(H) = 1 - \cos 3.6^\circ \Delta H \quad (2)$$

The greater real than apparent simplicity is due to the fact that the quantity 1 — cos $3.6^\circ\,\Delta$H is in any actual case a simple number whose value may be read off at once, for every tenth hue step, in Table II. The Greek *deltas* are of course simply the symbols for color-difference or change. That is, ΔH, ΔC, and ΔV are the fading changes in the Munsell hue, chroma and "value," respectively. It may be noted also that for many cases the change in chroma is small, so that C_1C_2 may be replaced by the square of the mentally-averaged chromas. For example, when the chroma changes from 10 to 8, or from 12 to 10, large changes, the error created by this approximation is only a little more than, or a little less than one percent, respectively.

It should be further noted that, though evidence of the general accuracy of the formula has been given in a paper (*6*), the accuracy can be no greater than that of the Munsell visual spacing, on which the formula is based.

The unit of color difference in the I_4 formula is one chroma step, a relatively large unit. The unit used in the Nickerson Index of Fading is 1/3 chroma step. This relation of the units is confirmed approximately in the data of Table I. The Judd or National-Bureau-of-Standards (NBS) unit is, according to Nickerson (*8*), larger by the factor 1.28, while the Adams unit is only 1/36 the Nickerson unit.

The necessity for a new formula was recently emphasized by the following observations. In a wool-dye sample book, 2% and 0.5% dyeings of many dyes are shown side by side. The total color-difference between the 2% and the 0.5% dyeings for the blues appears much larger than for the yellows. Eight observers judged the 2 — 0.5% differences for a page of blues to be roughly twice the 2 — 0.5% difference for a page of yellows. Calculations by the Nickerson and Balinkin formulas for six blues and six yellows on these pages showed the comparative magnitudes reversed from those actually observed, with Balinkin's not as good (blue: yellow = 0.67:1) as Nickerson's (0.83:1). The new formula was much better (blue: yellow = 1.56:1). Similar relations may be found in Table I.

Inspection of the nature of the differences for various colors showed that the "value" difference for the yellows averaged only 0.4 value step, for the blues 1.5 step; and that the better performance of the new formula was in large part due to the fact that it weighted value more heavily in relation to chroma.

The number by which ΔV is weighted (multiplied) in formula (1) is taken because of experimental work given in detail (*6*). The relative visual magnitude of one Munsell value step, compared to one Munsell chroma step, was thus taken at the rounded ratio 4:1. It is well known that this relation changes with the conditions of observation. For example, if the samples being compared are held too far apart, the visual magnitudes of hue-difference or chroma-difference change very little or hardly at all; but the magnitude of the value difference rapidly falls off apparently as the samples are increasingly separated.

The relative magnitudes of the units of hue and of chroma are fixed by Munsell circular geometry. In this system as usually plotted (hue as an angle and chroma as a radius, with the neutral grays at the center), 11 Munsell hue steps are equivalent to 4 Munsell chroma steps at average chroma 6 (see (*6*)). As indicated above, this is equivalent to an 11:8 ratio at chroma 12, or to an 11:2 ratio at chroma 3.

Bellamy and Newhall (*9*), from experiments determining the H, C, V differences just great enough to be perceived in half the trials, found:

$$1 \text{ step of V} = 8 \text{ steps of C} = 22 \text{ steps of H} \quad (\text{at C} = 6) \quad (3)$$

This is almost exactly the relation of C:H involved in the Munsell geometry. Miss Nickerson found the experimental relation for large color differences quite early (1935-36) (*8*).

$$1 \text{ step of V} = 2 \text{ steps of C} = 3 \text{ steps of H} \quad (\text{at C} = 5) \quad (4)$$

This great disagreement illustrates how much the relative magnitudes of the units of hue, chroma and value change with conditions of observation. The author's experimental relation,

$$1 \text{ step of V} = \text{approximately 4 steps of C} \quad (5)$$

is seen to be intermediate between those found by Bellamy and Newhall and by Nickerson. Hugh R Davidson of this Laboratory found the relation to be about V:C = 3:1 for conditions of observations similar to the author's. According to Dr D B Judd (*10*), the National Bureau of Standards (NBS) units of color difference correspond to the equivalence of 1 step of V, 1.6 steps of C and 5 steps of H (at C = 5).

ON-TONE FADING

The primary purpose of this paper was a study of on-tone fading, here defined as the color-change due to mere concentration-change only. In order to study this effect, several hundred wool and cotton dyeings in pairs, including some with dye mixtures, were examined. By "pairs" we mean two dyeings of each dye, one at each of two nominal strengths. As indicated above, the largest group was studied at 2% and 0.5% concentrations on the weight of fiber; the results are reported in Table I. But other strength changes mentioned above were also studied, with similar results.

The method of study was to compute the magnitudes of (on-tone) fading from the Munsell "Re-notation" specifications (*5*) of, say, the 2% and 0.5% dyeings, using the new color-difference formula; that is, to compute the color difference or fading between these two dyeings of each dye. The Munsell specifications were obtained through spectrophotometric measurements, as previously mentioned. The wool dyeings are marked "W," cotton dyeings "C," and wool-dye mixture dyeings "M" in Table I. The data are plotted in Figures 2, 3 and 4. The magnitude of on-tone fading, computed from the new formula, is given as I_4 in column 11 of Table I. Here the subscript 4 is for the purpose of recalling the use of the ratio V:C = 4:1, which was employed in the formula.

Except for a few scattered colors, it is clear that the amount of the total color change, here arbitrarily called the "perceptibility," is, as a first approximation, a function of the original (2%) hue only. On the whole, there is more departure from the average relation (solid line) for colors of low chroma than for more saturated ones; and the deviated points can for the most part be predicted.

At the start of this paper, the prejudice against hue-change in fading was pointed out, indicating that this makes acceptance or rejection of a fading not proportional to the perceptibility or amount of total color-

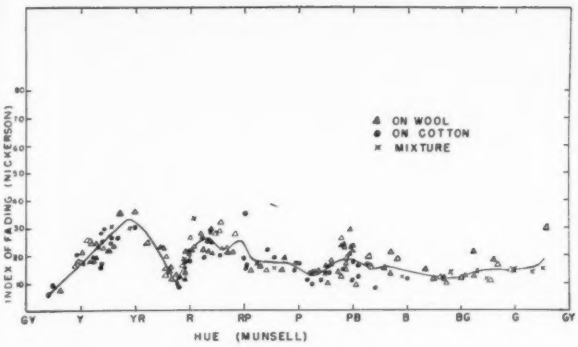

Figure 5

The Nickerson "Index of Fading" I_N.

Remarks on the hue scale and textile fiber dyed are as in previous figures. The data are for the "on-tone" fading from 2% to 0.5% concentration on the fiber. Note the relative constancy of the indexes, taken from the last column of Table I. Note that the fading index for many yellows is equal to or greater than that for blues (PB), the reverse of the facts as seen by our observers.

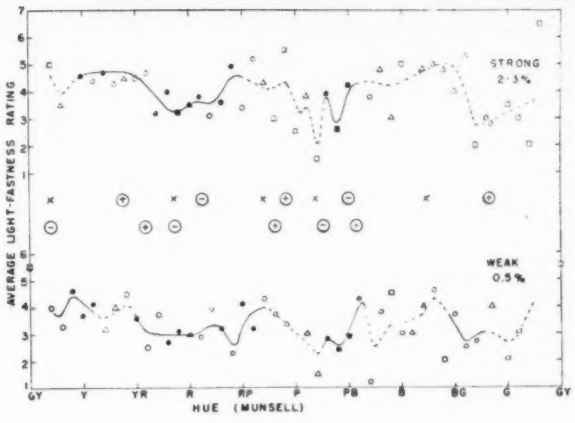

Figure 6

Average Light Fastness Ratings in 50 Hue Ranges as a Function of Hue for Strong and for Weak Dyeings.

Here cotton and wool are considered together. The points are plotted at the center of a 2-step (Munsell) hue range. The reliability of the data is taken as parallel to the number of cases averaged, these being indicated as follows: ■, 15-24 cases; ▲, 11-24 cases; ●, 6-10 cases; O, 3-5 cases; Δ, 2-3 cases; and □ only one case. For comparison, in the upper row near the horizontal center, the maxima and minima and zero-axis crossing points of Figure 1 are shown by +, — and x, respectively. Similar data from Figure 3 are shown for "perceptibility" from Figure 3 (lower row).

change. In Column 10 of Table I, the hue component of the color change is arbitrarily multiplied by 5. In column 12, a new total color-change including this enhanced hue-change, called the "rejectability" (J_1), is given. The rejectability (negative of acceptability) is plotted in Figure 3. The remarks which apply to Figure 2 apply here too. In Figure 4, the average "perceptibility" of the change (2% to 0.5%) is plotted (below) along with the rejectability (above).

It is clear that this weighting by a factor of five to obtain rejectability, which it is believed is somewhat more than occurs in practice, can only be of much consequence in the region from reddish yellow through red-purple, not including colors near Munsell 8 R (yellowish reds). Attention may be called also to the striking difference between greenish yellows and oranges in the case of either perceptibility or rejectability. Otherwise there is rough constancy except for definite minima at the Munsell hues 8 R, 0.5 P and 5 B. The extra weighting given to hue change by many "consumers" becomes very significant only in the red-to-yellow region.

The Nickerson Index of Fading I_N *(8)* is given in the last column of Table I and in Figure 5. It has been mentioned previously that it failed to reproduce our textile-dyeing data satisfactorily. The plot of the data shows that this index is very roughly constant for various hues. Particular attention has already been called to the comparison of the 2% → 0.5% change of yellows relative to blues, and the fact that the Nickerson and Balinkin formulas give the reverse of the observed facts. The new formula comes much closer (see above). Evidence was given that at least part of the difference in success of the new and old formulas lies in the different weighting of "value" in relation to chroma. It was the failure of the Nickerson and Balinkin formulas to reproduce the facts for the textile dyeings changing concentration, which led to the resuscitation of the new formula, developed in 1945.

TABLE II

Values of ϕ (H) = 1–COS 3.6° ΔH

ΔH	Φ(H)	ΔH	Φ(H)	ΔH	Φ(H)	ΔH	Φ(H)
0.0	.0000	4.0	.0314	8.0	.1237	12.0	.2710
.1	.0000	.1	.0330	.1	.1267	.1	.2753
.2	.0001	.2	.0346	.2	.1298	.2	.2797
.3	.0002	.3	.0363	.3	.1329	.3	.2841
.4	.0003	.4	.0380	.4	.1361	.4	.2885
0.5	.0005	4.5	.0397	8.5	.1393	12.5	.2929
.6	.0007	.6	.0415	.6	.1425	.6	.2974
.7	.0010	.7	.0433	.7	.1457	.7	.3018
.8	.0013	.8	.0451	.8	.1490	.8	.3064
.9	.0016	.9	.0470	.9	.1523	.9	.3109
1.0	.0020	5.0	.0489	9.0	.1557	13.0	.3155
.1	.0024	.1	.0509	.1	.1591	.1	.3201
.2	.0028	.2	.0529	.2	.1625	.2	.3247
.3	.0033	.3	.0549	.3	.1659	.3	.3293
.4	.0039	.4	.0570	.4	.1694	.4	.3340
1.5	.0044	5.5	.0591	9.5	.1729	13.5	.3387
.6	.0050	.6	.0613	.6	.1765	.6	.3434
.7	.0057	.7	.0634	.7	.1801	.7	.3482
.8	.0064	.8	.0657	.8	.1837	.8	.3529
.9	.0071	.9	.0679	.9	.1873	.9	.3577
2.0	.0079	6.0	.0702	10.0	.1910	14.0	.3626
.1	.0087	.1	.0726	.1	.1947	.1	.3674
.2	.0095	.2	.0749	.2	.1984	.2	.3723
.3	.0104	.3	.0773	.3	.2022	.3	.3772
.4	.0113	.4	.0798	.4	.2060	.4	.3821
2.5	.0123	6.5	.0822	10.5	.2098	14.5	.3871
.6	.0133	.6	.0849	.6	.2137	.6	.3921
.7	.0144	.7	.0873	.7	.2176	.7	.3971
.8	.0154	.8	.0899	.8	.2216	.8	.4021
.9	.0165	.9	.0925	.9	.2255	.9	.4071
3.0	.0177	7.0	.0952	11.0	.2295	15.0	.4122
.1	.0189	.1	.0979	.1	.2335	.1	.4173
.2	.0201	.2	.1006	.2	.2376	.2	.4224
.3	.0214	.3	.1034	.3	.2416	.3	.4276
.4	.0227	.4	.1062	.4	.2457	.4	.4327
3.5	.0241	7.5	.1090	11.5	.2499	15.5	.4379
.6	.0255	.6	.1119	.6	.2541	.6	.4431
.7	.0269	.7	.1148	.7	.2583	.7	.4484
.8	.0284	.8	.1177	.8	.2625	.8	.4536
.9	.0299	.9	.1207	.9	.2667	.9	.4589
						16.0	.4642

JUDGMENT OF FASTNESS OF YELLOWS AND BLUES

The very small change of yellows, especially greenish yellows, for a given change of concentration, as seen in Figures 2 and 4, when compared to other changes (as in blues), explains why dyers complain that it is difficult to judge the strength and fastness of yellows. This question will be considered in more detail later.

IS FASTNESS RATING LARGELY DEPENDENT ON THE PERCEPTIBILITY OF THE COLOR CHANGES?

The question has often been raised as to whether the perceptibility of the changes which occur in fastness tests affects considerably the fastness ratings of dyestuffs. This question has been considered in the present work; and in this connection reference may be made to Figure 6. Here the average light-fastness ratings of a large number of wool and cotton dyes have been plotted as a function of hue. For comparison, near the horizontal center the maxima and minima and zero-axis crossing points (shown respectively by $+$, $-$ and $\times$) of the hue change of Figure 1 are shown (upper row); and similar data for perceptibility from Figure 2 are also shown (lower row). The fastnesses were rated on an 8-step scale, averaged for 50 hue intervals and plotted at the center of each hue (abscissa) interval. This was done for both weak dyeings (0.5%, below) and moderately strong ones (2-3%, above). The number of cases averaged is indicated by the symbols plotted as points, as explained in the key to the figure.

If the question at the head of this section were to be answered in the affirmative, then high fastness should correspond to low perceptibility of the color change (or perhaps to low hue change or low rejectability), and conversely, low fastness rating should correspond to large perceptibility. Some minor correlations of this sort may be found in Figure 6; but in general such correlations are poor. This evidence indicates only that fastness ratings are at least not primarily a matter of perceptibility of the change, or that the color changes in light-fastness tests are not primarily due to loss of concentration only.

THE PROCESS OF JUDGING STRENGTH OF DYEINGS

The contrasting situations referred to above when color changes in blue and yellow dyeings are compared, and the difficulty of judging strengths and, hence, fastnesses of yellows, suggested the advisability of examining typical yellows and blues (and also other hues) more closely in this connection. This material has since been published (*11*), so will be reviewed only briefly here.

Various formulas have been proposed for relating dyestuff concentration to measured reflectance, some of them rather complex; and there is little doubt that the several constants involved may vary considerably with type of fiber and dyeing, when dealing with a complete range of dyeing strengths. However, it has been found for 26 wool dyeings that the logarithm of concentration plotted against square-root of reflectance (tristimulus value Y) gives practically straight lines for concentrations of dye (relative to weight of fiber) from 0.1% to 5%. The slopes of the reflectance-concentration curves were nearly constant from bluish reds through purple, violet and blue to blue-green, but very low in the yellows and low in the oranges. Further, the relation of logarithm of concentration to "excitation purity" (hereafter called merely "purity") shows some curvature for the higher strengths, but not nearly as much as when log conc is plotted against visual steps (Munsell "value").

More than the possible use of the concentration-reflectance relation as a possible simple practical method for determination of dyeing strengths, the author was interested in the analysis of the dyer's and colorist's subjective evaluation of "strength" from the more objective realities presented to him in judging dyeings. Imperial Chemical Industries workers (*12*) had presented evidence that experienced colorists judged strength largely (but not wholly) on the basis of saturation (Munsell chroma), the visual correlate of purity, while less experienced persons judged largely on the basis of the usually more readily perceived lightness change, the correlate of reflectance change. But the present author's "curves" for yellows had slopes so very small that even experts could not place reliance on reflectance change, and in these cases must have been forced to reliance upon purity. But the purity, and especially the saturation, curves "doubled back" so much in many cases at higher concentrations, that reliance must be put in part on reflectance (except for yellows). For the curvature was often enough that there were *two* values of concentration corresponding to a single value of purity or saturation (with purity better than saturation). It is clear that the colorist's judgments of strength are based upon a very complex and subtle art, which in the case of strong yellows must involve much uncertainty. Data of the nature discussed here make one wonder how the colorist succeeds as well as he does and leads to increased respect for him.

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ABSTRACTS

Human Color Vision

W R Lang, *Textile J Australia* 26, 88-91, March 20, 1951.

"Color blindness" is a subject that must be of some interest to dyers and colorists, especially when one realizes that at least eight per cent of the male population is concerned with the defect in some degree. It is inherited, occurs on the male side of the family, and is practically nonexistent on the female side, and unfortunately is not curable. Only about one woman in 500 is color-blind. However, a woman whose father is color-blind may transmit the defect to her sons.

It is said that there are three forms of color blindness, of which the first is total color blindness (only 50 cases had been recorded by 1939); the second is blue-yellow color blindness, in which blue and yellow cannot be seen, but red and green can, and this is of small practical significance; the third is red-green color-blindness, where blues and yellows predominate in the color appreciation, which because of the numbers concerned and the colors confused is of major importance.

What are the color sensations of the red-

green blind? With some, yellow and blue may replace all the other colors, i e, red, orange, yellow and green may be seen as different shades of yellow; blue and violet as different shades of blue. Sometimes the green may not be replaced by yellow, but appears as a shade of gray. The extent of the neutral band varies with the defect.

The major portion of the article is occupied with a discussion of the theories which have been advanced to explain the phenomena of color perception by the eye. The author states that light passes into the human eye through the cornea, then the aqueous humor, the aperture in the iris, and after passing through the crystalline lens and the vitreous humor, is focussed on the retina. The conversion of light energy into nervous energy takes place in the physiological processes in the retina. He comments that little enough is still known about the way in which light rays stimulate the retinal receptors, and less is known about the conversion in the brain of nerve impulses into perception.—WHC

The Premetallized Wool Dyestuffs.

R S Mayston, *Textile J Australia 26*, 191-4, April, 1951.

The premetalized wool dyestuffs are soluble chromium complexes of lake-forming azo dyes. They are prepared from suitable chrome dyes or other dyes which may be unsuitable as ordinary chrome colors, the predominating feature being the presence of an ortho dihydroxy structure in the intermediates. Thus the chosen dyestuff is reacted with chromium salts to produce a new dyestuff in which the mordanting metal (chromium) is already incorporated in the dyestuff, which may now be applied in a manner resembling the level dyeing acid dyestuffs, yet the dyeings attain a wet fastness approaching that of chrome colors. In all cases the dyes are of the azo class, and it is not surprising that the range is deficient in bright blues, which are normally supplied by members of the anthraquinone class.

A characteristic feature of this class of dyestuff is the high percentage of sulfuric acid required for dyeing. It has been found that with these dyes a pH of 2.7 to 3 in the dyebath (equivalent to about 4 per cent of acid on the weight of the wool) gives maximum exhaustion, but the dyeings so produced are "skittery". By an increase of the acid content to a pH of 2, the exhaustion is retarded and solid shades result.

A brief consideration is given to the theory underlying the use of certain auxiliary products, such as Neolan Salt P, Palatine Salt, etc, which when used in conjunction with sulfuric acid permit the amount of acid to be reduced to 5 per cent or thereabouts. These agents are neutral and do not split off acid as is often assumed. One type, such as Neolan Salt P, has an affinity for the dyestuff, thus competing with the wool for the dye, thereby promoting leveling. Chemically these products are based on ethylene oxide condensates. The second type of leveling agent is typified by Palatine Salt N. This product has an affinity for the wool, being chemically of the alkyl aryl sulfonate class, which in an acid bath is readily absorbed by the wool, while the slower diffusing dyestuff has to compete with the agent for the wool, thus promoting leveling. The two types of agents should never be used together in the one dyebath.

Although the usual practice calls for dyeing from an acid bath, it may surprise some to know that selected members of the range dye reasonably well from a neutral bath. A recent report on German methods mentions that Palatine Fast plus direct colors were advocated for union dyeing in Germany. As compared with normal dyeing, neutral dyeings show only slightly inferior wet fastness, while light fastness appears unaltered.

In the dyeing of pieces containing mixed or tippy wools, this type of dye tends to accentuate the differences between them.

An outstanding feature of this class of color as compared with others is that when dyed from a weakly acid bath, i e, pH 5.5, there is a considerable difference in shade between normal and chlorinated wool, but on increasing the acid content up to pH 2 the two types of wool are dyed to nearly the same shade.—WHC

Improving the Tenacity of Protein Rayons

R W Moncrieff, *Skinner's Silk & Rayon Rec* 25, 538, 540, April, 1951.

The outstanding defect of regenerated protein fibers, whether made from casein, soya-beans, peanuts or corn, has always been their low strength and particularly their low wet strength. The root of the difficulty is that to spin a regenerated protein fiber, the protein must be brought into solution. Dissolving proteins is usually accompanied by a certain amount of molecular degradation, so that when the protein is precipitated in fiber form, it is not the same as the original protein from which it was made, but has suffered partial degradation. Invariably molecular change of this sort manifests itself as a loss fn tenacity, especially in the wet state.

Two kinds of degradation are likely to occur:

(1) Hydrolysis of the main polypeptide chains resulting in shorter molecules, less *fibrous* molecules, and consequently in fibers with less desirable properties, notably lower strength.

(2) Breakdown of cross-linkages which hold the main polypeptide chains together. This results in loss of molecular stability and in enhanced susceptibility of the fiber to chemical and biological attack.

Because the defects of regenerated protein fibers have been most serious when the fibers have been wet, an obvious line of attack has been to make the molecular structure of the fiber less accessible to water molecules, and therefore less liable to damage from immersion in water. It has long been known that esterification reduces the affinity of cellulose for water. Thus, Aralac, the fiber formerly made from casein, was given a mild acetylation to improve its properties, and Vicara, the fiber made from corn protein, is believed to have undergone a partial acetylation during production. However, acetylation will not repair the damage suffered by the fiber from the rupture of its cross-linkages.

A cross-linking agent which has been widely used and which has become indispensable in protein fiber production is formaldehyde. This forms methylene linkages between adjacent polypeptide chains. The result is improved elasticity and strength, particularly in the wet state.

More recently, a treatment with mercuric acetate, following the formaldehyde treatment, has been suggested. This is said to result in greatly increased wet strength. Salts of uranium have also been recommended for this purpose. It would seem that the way is reasonably clear for the development of peanut fiber of a strength better than has hitherto been achieved.—WHC

Vicara Staple Fiber: Its Uses, Properties and End Products

L B Whitcomb, *Can Textile J* 68, 51, 53, 65, 67, 69, May 25, 1951.

The author first describes briefly the production of the Vicara fiber from corn protein as carried out by the Virginia-Carolina Chemical Corporation. He then discusses the properties of the fiber in detail.

Vicara is a uniform fiber, light golden in color. Under the microscope it appears as a cylindrical, translucent rod with a nearly circular cross-section. The specific gravity is 1.25. It has an elasticity comparable to animal fibers, and its tenacity (dry) is 1.10 to 1.20 grams per denier. It is resilient and resists deformation to a marked degree.

Vicara has warmth equal to wool. Laboratory tests indicate that its insulating value is similar to that of animal fibers in fabrics of like construction.

Vicara is less flammable than cellulosic fiber; the burning rate is slow, slightly faster than wool. The fiber is inherently moth-resistant and is highly mildew-resistant. It is nonitching and has never been known to cause an allergy.

Vicara has an affinity for most types of dyestuffs. Satisfactory to excellent fastness can be obtained. As with other fibers, selected dyes which are best suited to the end use should be used.

In dyeing mixtures of Vicara and wool, acid, metalized and chrome colors can be used. The level dyeing acid dyes yield good unions at a pH of 2.5 to 3.5 which may be obtained with formic acid. The dyestuffs may exhaust differently on the two fibers up to 200° F, but from 200° to 212° the two fibers should equalize in shade.

The behavior of Vicara towards direct dyes is similar to that of natural protein fibers. Blends of Vicara and cellulose are best dyed with a combination of direct dyes leaving wool white and neutral-dyeing acid dyes.

Similarly, Vicara and acetate mixtures may be dyed with acetate dyes supplemented with neutral-dyeing acid dyes.

Most acid colors have a greater affinity for nylon than for Vicara. However, the acid dyes may be retarded on nylon by the use of a long chain alcohol (e g, Duponol D). By careful adjustment of the alcohol, uniform shades may be obtained on Vicara and nylon with most acid colors, using Glauber's salt and formic acid. Vicara and nylon may also be dyed with several milling colors.

The author gives a selected list of suitable dyes for Vicara in each of the various dye classes. He recommends particularly, for all-around fastness, certain metallized dyes.

For bleaching, he states that hydrogen peroxide can be used, followed by a treatment with sodium formaldehyde sulfoxylate.

The various advantages of Vicara when used in blends with other fibers (cotton, wool, nylon, acetate, Dynel) are emphasized, particularly its crease-resisting properties, soft feel, and good dimensional stability.—WHC

Here's the Dacron Story

L L Larson, *Textile World* 101, 112-13, 312-16, June, 1951.

The most natural outlet for Dacron polyester fiber appears to be in suitings and all types of outerwear. The contributions of Dacron to suitings are:

Excellent appearance: color, drape, tailoring qualities

Wrinkle resistance and press retention: wet, moist, or dry

Dimensional stability

Launderability without shrinkage or wrinkling

Economy.

Resilience is a keynote of a good suiting fabric. Resilience is the keynote of Dacron, just as it is the keynote of wool. There is a fundamental difference, however, between the resilience of the two fibers that is demonstrated by the ability of Dacron to maintain its high resilience in moist or wet conditions.

High wrinkle resistance and press retention under wet as well as dry conditions have a profound significance in actual wear. A suit of Dacron is unaffected (aside from getting wet) when a wearer is caught in a rainstorm. After drying, the suit of Dacron looks just as it did before it became wet and needs no pressing.

Manufacturers of summer suits have been seeking a solution to the problem of puckering and fabric movement that is caused by subjecting garments to high humidities, and also puckers and shrinkage that occur at times in cleaning operations. Dacron promises to be a practical solution to these problems.

Fabrics of Dacron are not only stable to changes in relative humidity, but they are also stable to washing as well as to dry cleaning. Laboratory tests showed a 7.8-oz tropical of Dacron shrank less than 1 per cent when washed eight times at 140° F.

Owing to its excellent abrasion resistance, suits made from Dacron would be expected to have good wear life. This is being confirmed in actual wear tests.

While Dacron will be used alone in outerwear, it will also contribute significant functional properties in blends with other fibers. In this way each fiber will be engineered to make its particular attributes most effective. Considerable work has been done on blends of Dacron with wool and with rayon.

All of the new fibers seem to have their dyeing headaches, and Dacron is no exception. A good job can and is being done, but the job of dyeing is not easy. Special techniques, such as the use of selected dyeing assistants and dyeing for long periods at the boil, are required. Light fastness of the order required for specific end uses has been obtained. Furthermore, dyestuff procedure developments now in progress promise very outstanding light fastness in a complete range of colors. Wash fastness of dyes is generally excellent on Dacron. The dye is hard to get on, but once on, it is hard to wash off.

One of the properties of knitting yarns of Dacron is the excellent elastic recovery that promotes good shape retention in sweaters and hose.

The high tenacity and strength of Dacron are utilized in fire hose fabric, V-belts, and ropes. Other important uses are in laundry nets and press cloths, and in sewing thread. —WHC

Stains: Their Cause, Cure and Removal.

A Carpenter, *Textile Recorder 69*, 93-5, June, 1951.

Quite a lot of stains encountered by the commission dyer are outside his control, being present in the goods on receipt from the maker. Such stains are caused by dirty machine oil, colloquially known as "swarf", containing, in addition to lubricating oil, carbon and finely dispersed metal particles. It is important to remove these stains *before* bleaching or dyeing.

Three alternative methods of attack present themselves, namely, to increase the strength of the scouring liquor, to give a pretreatment in bulk, or to pick out the stains and treat each by individual "spotting".

For the first method special solvents, such as emulsions of trichlorethylene, are marketed for addition to the scour, (In the writer's opinion, however, these rarely achieve the desired result unless used in uneconomical quantity). What little improvement is given by ordinary dosage is often more cheaply obtained by increasing the quantity of soap or synthetic detergent.

More promising results are obtained by presoaking the batch in a more concentrated bath (which is saved and used over again) containing about 2.5 per cent of the solvent emulsion plus a similar amount of soap or sulfonated fatty alcohol, the temperature depending on the type of fiber being processed and on the volatility of the solvent. The writer also recommends the use of nonionic detergents, while Dr Trotman has suggested a fairly high concentration of sulfonated fatty alcohol with substances such as Irgalon BT (Geigy).

The third method, individual "spotting", consists of examining the goods before scouring and rubbing each stain with some substance which will loosen it sufficiently for it to come away in the scour. It has the merit that only the stained part is given extra treatment, and there is therefore no danger of overprocessing the rest of the batch. The writer recommends for this purpose an economical and nonvolatile home-made mixture of equal parts of Sextol, oleic acid and triethanolamine. It is advisable to scour immediately after spotting, or the solvent itself may dry in and stain.

Condensation droppings from the roof or overhead pipes usually contain iron rust. Iron stains may be dealt with by spotting with a 10 per cent solution of oxalic acid, rinsing, and neutralizing any excess with dilute ammonia. When dealing with bleached wool, there is a danger that the oxalic acid itself will cause slightly discolored patches, and in this case it is best replaced by hydrochloric acid, or better still, by hydrofluoric acid.

Another method of removing iron stains, useful when they are numerous, is to run the entire batch into a warm solution of a metal sequestering salt such as Calgon T.

Finally the writer discusses copper stains, usually due to direct contact of the material with corroded copper or brass. He states that these stains—which may be identified by a deep red coloration with sodium diethyldithiocarbamate—are not easy to remove. On the cellulosic fibers it is recommended to boil for 30 minutes in a 0.2 per cent solution of Irgalon acidified with tartaric acid. This of course involves treatment of the whole batch. For odd stains, the only spotting solutions of any value are the alkali cyanides, which being virulent poisons must be used with care.—WHC

Proceedings of the
American Association of Textile Chemists and Colorists

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SEPTEMBER 3, 1951

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Calendar of Future Meetings

COUNCIL: Oct 18 (Hotel Statler, N Y); Nov 16 (Hotel New Yorker); Jan 18, 1952; April 18, 1952; June 20, 1952; Sept 19, 1952 (all in New York); Nov 6, 1952 (Boston).

GENERAL RESEARCH COMMITTEE: Sept 28 (Swiss Chalet, Rochelle Park, N J). Other dates and sites are the same as the Council's.

NATIONAL CONVENTIONS: 1951—October 17-19, Hotel Statler, New York, N Y; 1952—November 6-8, Boston, Mass; 1953—Sept 17-19, Hotel Stevens, Chicago, Ill; 1954—Atlanta, Ga.

HUDSON-MOHAWK SECTION: Sept 21 (Jack's Restaurant, Albany); Oct 26 (Hotel Utica, Utica N Y); Dec. 7, Feb 1, 1952, Mar 21, 1952, May 2, 1952 (all at Jack's Restaurant); June 20, 1952 (Annual Outing).

MID-WEST SECTION: Sept 29 (Morrison Hotel, Chicago, Ill.)

NEW YORK SECTION: Sept 28 (Swiss Chalet, Rochelle Park, N J); Nov 30 (Swiss Chalet); Jan 11 (Hotel New Yorker); Feb 29 (Hotel McAlpin, New York); April 18 (Swiss Chalet); May 16 (Swiss Chalet); June 20 (Outing).

NORTHERN NEW ENGLAND SECTION: Oct 26 (LTI, Lowell, Mass); Nov 30 (Annual Meeting, Boston, Mass).

PACIFIC SOUTHWEST SECTION: Oct 6 (Annual Outing, Ojai Valley Inn, Ojai, Cal); Jan 11, 1952; March 28, 1952.

PHILADELPHIA SECTION: Sept 14, Oct 26, Dec 7, Jan 18, 1952 (all at Kugler's Restaurant, Philadelphia).

PIEDMONT SECTION: Sept 22 (Annual Meeting, Charlotte, N C).

RHODE ISLAND SECTION: Oct 26 (Providence Engineering Society; Nov 16 (Johnston's).

SOUTH CENTRAL SECTION: Dec 1 (Hotel Patten).

SOUTHEASTERN SECTION: Sept 8 (Columbus, Ga); Dec 8 (La Grange, Ga).

WESTERN NEW ENGLAND SECTION: Sept 28, Nov 9, Dec 14 (all at Rapp's Restaurant, Shelton, Conn).

REPORT OF THE NOMINATING COMMITTEE

THE Councilors representing Sections, in their capacity as Nominating Committee, have nominated C Norris Rabold for President in the year 1952. In accordance with the Constitution, additional nominations, each signed by any fifty or more Senior members, may be filed with the Secretary not later than October first, and will receive equal standing on the ballot.

Under the amended Constitution, Senior members of the Northern New England, Rhode Island and Western New England Sections will elect a Vice President for the New England Region. The Councilors from this Region have nominated Raymond W Jacoby and George O Linberg.

The Councilors from the New York, Philadelphia and Hudson-Mohawk Sections have nominated J Robert Bonnar and Arthur W Etchells as candidates for Vice President from the Central Atlantic Region.

The Councilors from the Piedmont, South Central and Southeastern Sections have nominated Wyss L Barker and Samuel L Hayes as candidates for Vice President from the Southern Region.

The Councilors from the Mid-West, Pacific Southwest and Pacific Northwest Sections have nominated Arthur T Brainerd as candidate for Vice President from the Western Region.

Additional nominations for Regional Vice President, each signed by twenty-five or more senior members of the region involved, may be filed with the Secretary not later than October 1, and will receive equal standing on the ballot.

HAROLD C CHAPIN, *Secretary*

INTERSECTIONAL CONTEST COMMITTEES AND PAPERS

ANNOUNCEMENT has been made of a number of the committees and titles of papers in conjunction with the Intersectional Contest to be held on October 19th as part of the proceedings of the Thirtieth National Convention, Hotel Statler, New York. Details are:

MID-WEST SECTION

TITLE—"Dynel and Fiber V."

COMMITTEE—

Dr L J Armstrong, *Chairman*

NEW YORK SECTION

TITLE—"An Approach in the Study of Factors which Determine Fabric Soiling."

COMMITTEE—

Dr Eugene W K Schwarz, *Chairman*
Edmund A Leonard, *Secretary*
Kenneth H Barnard — John F Hagen
Emil C Hansen — George A Slowinske
Dr Emery I Valko

PHILADELPHIA SECTION

TITLE—"The Use of Synthetic Resins for Imparting Crease Resistance to Cottons."

COMMITTEE—A C Nuessle, *Chairman*

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E C Diehl	A E Raimo
R H Drukker	M J Reider
A W Etchells	F H Riale
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T H Hart	R B Stehle
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RHODE ISLAND SECTION

TITLE—"The Continuous Dyeing of Synthetic Fibers."

COMMITTEE—

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Fred R Tripp	David Hardman
George H Wood	Richard H Lewis

JUDGE—Harold B Sturtevant

SOUTH CENTRAL SECTION

TITLE—"Toward a Simple Mechanical Means of Judging Hand."

COMMITTEE—

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JUDGE—Joe T Bohannon, Jr.

SOUTHEASTERN SECTION

TITLE—"A Study of the Effect of the Structure of Cotton Cloth and Mercerization on the Fastness Properties of Vat Colors."

COMMITTEE—J H Stradley, *Chairman*

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Philadelphia Section——

WHAT'S NEW IN SPECTROPHOTOMETRY: PROGRESS OF SPECTROPHOTOMETRY IN THE TEXTILE INDUSTRY TO 1951*

E I STEARNS

Application Research Department of the Calco Chemical Division of the American Cyanamid Company

A review of the literature has been made and the thirty-two applications of the spectrophotometer in the textile industry that have been reported are discussed. A list is presented of sixteen fundamental formulas that are needed for the interpretation of spectrophotometric data in textiles; included in the discussion is a recommendation of which formula to use for each application. Brief suggestions are made for the equipment of a spectrophotometric laboratory and for methods to be followed in measuring solutions and fabrics.

INTRODUCTION

THERE are many indications that the spectrophotometer is finding increasing use in the textile industry and is well established as a tool to assist the dyer. One evidence of this is the fact that, during the last three years, 1948 to 1950, there have appeared in the *American Dyestuff Reporter* thirty-nine articles which deal with data that have been obtained with a spectrophotometer. Another evidence of the acceptance of spectrophotometry is illustrated in the paper presented by the Rhode Island Section *(82)*, "Some Conditions Affecting the Application of Vat Colors". In that paper there were ten conclusions drawn, all of which related to the properties of vat dyes. In that study the spectrophotometer was used to measure the relative strength of vat dyes on cotton fabrics. Also, the spectrophotometer was used to measure the amount of vat dye in the exhausted dyebath. If this work had been done ten years ago, one of the outstanding conclusions of the paper would have been that the spectrophotometer could be used for these evaluations. Today, however, these spectrophotometric applications are so well established that they deserve mere casual mention in the body of the report.

PURPOSE

The development of a science, and the application of spectrophotometry to the textile industry is no exception, is advanced in a great many ways by a great many contributors. One phase is the theoretical background. Several scientists may attack a similar problem and come up with slightly different answers. Over a period of years these proposals are tested by workers in the field, and some are rejected as being incorrect while others are rejected as being too complicated. Finally, a practical formula emerges, which is simple enough and yet correct enough. As an example, one of the problems in the spectrophotometry of textiles is the relationship between reflectance of light and concentration of dye on the fabric. This has received much attention, and six or seven different mathematical relationships have been proposed by different authors. One of the purposes of this paper is to sort out the most usable of these theoretical relationships. This has been done and the sixteen recommended formulae are listed and discussed below.

E I Stearns

Another phase in the advancement of a science is the practical application. In general, the investigators engaged in industrial work have not been able to wait for the complete development of theory and, consequently, have attacked their problems and arrived at workable solutions by using a variety of methods of analysis. For instance, one practical problem is the spectrophotometric measurement of color difference in a fabric before and after exposure to light. One method *(54)* that has been used is to measure the apparent reduction in concentration of dye during exposure. A second proposed method *(41)* is to measure the areas between the spectrophotometric curves before and after exposure. A third method *(101)* is to express the difference by means of a small-color-difference formula. A second purpose of this article is to recommend a method of interpretation which is believed to be most appropriate for each application reviewed in this paper. A recommendation of one method should not necessarily be construed as a criticism of another. Any of several methods might be successful for the purposes of a specific investigation. The recommendations are given to aid those engaged in spectrophotometry to select a preferred method of analysis from the literature.

One important and very perplexing question to a textile man is, "Will I find it an economic advantage to have a spectrophotometer in my mill?" The answer to this question must necessarily depend upon a study of the particular conditions in a particular mill. No general answer can be given. A third purpose of this article is to assist in answering this question by listing the applications that have been made in textile mills and by referring to literature where other investigators have reported their studies of the application. A man in a textile mill who is pondering this question can study the applications listed in this article and decide whether or not they will be found useful in his particular mill. He then should be in a better position to decide whether or not

* Presented in Philadelphia on April 13, 1951, before a joint meeting of the Philadelphia Section and of the Philadelphia-Wilmington Colorists.

the use of the spectrophotometer will save money for him.

SPECTROPHOTOMETRIC APPLICATIONS

A fairly comprehensive survey of the recent textile literature has been made in an effort to find all the various applications of spectrophotometry that have been reported. The following list of uses may be considered as a critical bibliography in that it attempts to give not only a brief description of the application, and references in which it was reported, but also makes specific recommendations regarding the method of interpretation of data for the particular application. In the discussion of methods of interpretation, references are made to mathematical formulas by number. These formulas are presented at the end of this article in the section, "Important Formulas".

1. DEGREE OF SOLUBILIZATION——In reference *(2)* is reported the use of the spectrophotometer to calculate the "degree of solubilization". This is of interest to the textile technologist because, as a general rule, the greater the solubilization the greater the stability of the suspension of dye. Also, exhaustion of acetate dyes or reduction of vat dyes is more rapid. The "degree of solubilization" is defined for acetate dyes as the ratio of the absorbency for light of the dye dispersed in water to the absorbency of the dye dissolved in acetone. In the case of dyes that do not readily form true solutions similar in color to their suspensions, for instance dispersed vat dyes, the ratio of the absorbency of one sample to the absorbency of another may be taken as a measure of relative dispersion. This index depends upon the theory that absorption of light increases as particle size decreases, and ultimately the greatest absorption of light is accomplished by the molecular dispersion of dye. It is recommended that Formula 2 be used to calculate an apparent absorbency index for the dispersed and dissolved states and that the ratio of these values be taken as relative "degree of solubilization".

2. DETERMINATION OF SOLUBILITY OF DYES——For a determination of the solubility of a dye, the dye powder is treated with a solvent under some particular conditions. Monego et al *(54)* reported a test which consisted of pouring hot water over the dye on a filter paper. In any event, the problem is then to measure the solution and to determine how much dye is in it. This has been successfully done by measuring the dye solution with the spectrophotometer as reported by the Mid-West Section *(51)*, by Monego et al *(54)* and by Zimmerman et al *(104)*. Formula 3 is recommended for these calculations.

3. STABILITY OF DYES——The stability of dyes in solution has been particularly of interest in connection with high-temperature dyeings. The use of the spectrophotometer to measure the concentration of dye before and after aging of solutions under elevated temperatures and pressures has been reported by the Philadelphia Section *(69)* and Royer et al *(85)*. The recommended method of interpreting data for this application is the determination of concentration by the use of Formula 3. The invalidation of results because of the formation of light-absorbing decomposition products is probably very slight for dyes showing only a small amount of strength loss.

4. TESTING DYES FOR STRENGTH——A great many investigators have reported the use of the spectrophotometer in the evaluation of dye shipments. These include the following: Reference *(2)*, Godlove *(21)*, Haller et al *(26)*, Mersereau et al *(49)*, Monego et al *(54)*, Pineo *(71)*, Rhael *(81)*, Simon *(89)*, and Stearns *(91)*.

Stearns *(91)* pointed out that the estimation of dye in solutions should be done with care because of three sources of error: first, there may be differences in exhaustion between standard and shipment; second, there may be differences in selectivity or ability to dye fibers evenly; and, third, there may be a slight shade difference within the commercial tolerance which, nevertheless, might be differently interpreted as strength by different observers. These precautions have occasionally been reiterated; for instance, in reference *(2)* it was said that differences in exhaustion may invalidate the results. The Piedmont Section *(70)* in their study of the stability of vat colors at elevated temperatures, pointed out that a spectrophotometer would measure the degree and state of reduction of vat dyes in solution, but colorless diluents, such as sugar or glucose, may interfere with the dyeing and thus spectrophotometric solution dye strengths do not necessarily correspond to fabric dye strengths.

The spectrophotometer is quite accurate in solution measurements. Rhael *(81)* reports that the spectrophotometer is superior to the eye in measuring small strength differences. Davis et al *(13)* report that the mean standard error for a photoelectric absortimeter is 1% concentration. Mersereau et al *(49)* report that the standard deviation including both solution preparation and dye homogeneity is 0.8%. Because of this inherent greater accuracy, it is probable that dyestuffs will continue to be measured in solution regardless of some uncertainty in the significance of the results. In fact, Mersereau et al *(49)* have reported that they have found solution testing in the mill of great value and recommend that the strength measurements so obtained be used to modify the dye-concentration ratios in the initial dyebath for routine mill dyeing.

All of these investigators recommended Formula 3 for this application. For details on how this formula is applied, recommended references are pages 357 to 364 of Mellon *(48)* and Simon *(89)*.

5. MEASUREMENT OF DYE EXHAUSTION FROM DYEBATH——Measurements of amount of exhaustion have been made by Clark et al *(8)*, Gunther *(25)*, Thomas et al *(98)* and Tucker *(99)*. Sometimes the purpose of this measurement is to help choose compatible dyes for combination dyeings. In other cases *(25)* the purpose is the evaluation of leveling agents. Formula 3 is recommended for this application.

6. MEASUREMENT OF DYE EXTRACTION——One method of determining the amount of dye on a fabric is to extract the dye with a suitable solvent and then to evaluate the concentration in the solution. This method has been reported by Witschonke et al *(103)* and Zimmerman et al *(105)*. The formula recommended for interpreting this type of data is Formula 3.

7. DETERMINATION OF EXHAUSTION RATES——The determination of exhaustion rate has been reported by Clark et al *(8)*, by Fidell et al *(18)*, Haller et al *(26)*, Monego et al *(54)*, New York Section *(56)*, Rhode Island Section *(82)*, and Royer *(83)*. Apparatus that can be used for this purpose has been described by Royer et al *(84)* and Simon *(89)*. The recommended formula for interpretation of data of this type is Formula 3.

8. MEASUREMENT OF RATE OF REDUCTION OF VAT DYES IN SOLUTION——Knowledge of the rate of reduction of vat dyes is of interest to an understanding of the dyeing properties of vat dyes and the selection of compatible combinations in a formulation. One report on this application is that of Clark *(7)*. A suitable instrument for carrying out this kind of test has been reported by Royer et al *(84)* and Simon *(89)*. The recommended formula for calculation of these results is Formula 4, in which it is assumed that the reduced form of the vat dye is dye "a" and the oxidized form is dye "b". Details on how this formula is applied can be found on pages 355-388 of Mellon *(48)*.

9. CONTROL OF CONCENTRATION OF DYES IN DYE BATH——Where the same shade is dyed over and over again, data from the spectrophotometer can be used to control the amount of dye in the initial dyebath and will help in the pro-

duction of constant shades on batch after batch. In the case of continuous dyeing, the composition of the feed liquor can be controlled. This application has been discussed in reference *(2)*, Haller et al *(26)*, Philadelphia Section *(68)* and Simon *(89)*. Of course, dye concentration is only one of the factors that must be controlled for uniform production. Examples of other controls that can be applied are given by Boden *(4)*. A detailed description of the recommended technique to use in analyzing spectrophotometric data for this application has been given by Davidson et al *(11)*. This consists of the application of Formula 3 if a single dye is present in the dyebath, or Formula 4 in the event that two dyes are present, or Formula 5 in the event that three dyes are present.

10. SELECTION OF BASE STOCK FOR DYEING——The color of the undyed fabric is always a contributing factor toward the color of the final fabric. Thus, if a sample of wool is slightly yellowish originally, it may be impossible to dye it a light blue color without some special treatment, such as a chemical bleaching. Mersereau et al *(50)* have reported that they have used the spectrophotometer to measure the reflectance of undyed wool and, from this, determine whether or not certain shades can be produced.

A recommended qualitative approach for this application is to note whether the reflectance of the standard shade is at any wavelength greater than the reflectance of the undyed wool. If this is true, then the undyed wool is not suitable as a base stock. If the reflectance of the standard approaches very closely to the reflectance of the undyed stock at some wavelength, a quantitative answer can be found with Formula 6.

11. DETERMINATION OF EXHAUSTION BY MEASURING DYE ON FABRICS——The measurement of dye strength on a fabric in connection with exhaustion studies has been reported by Luttringhaus *(42)*, Northern New England Section *(62)*, Rhode Island Section *(82)* and Royer et al *(85)*. Luttringhaus *(42)* assumed that log (1/R) was proportional to the depth of shade. The Northern New England Section *(62)* used a formula in which the strength was related to the areas underneath the spectrophotometric curves. In many literature references, the exact method used to convert spectrophotometric data to strength data is not clearly stated.

The recommended formula for determining the amount of dye on a fabric is Formula 8. The relative concentrations so calculated might then be used to evaluate strike, for instance, by a formula for strike in which the concentration of dye on the fiber after one minute is divided by the concentration of dye on the fiber after one hour.

12. THE EVALUATION OF STRIPPING AGENTS——Kaswell et al *(36)* have reported the use of a spectrophotometer in the study of an electrolytic method of stripping color from dyed wool. The spectrophotometric curves were used to distinguish between the samples which were unsuccessfully stripped by sulfoxylate and successfully stripped by an electrolytic process. The spectrophotometric curves were also used to show the effect of redyeing the electrolytically stripped fabric. The authors of this paper present the spectrophotometric curves themselves and assume that the interpretation of the curves is obvious to the reader.

As an index for the dye removed from the samples, it is recommended that Formula 8 be applied and that the apparent percent dyeing of the stripped cloth relative to the percent dyeing of the original cloth be used as a measure of stripping.

13. DETERMINATION OF FASTNESS TO CROCKING——The use of a spectrophotometer to determine the fastness to crocking has been reported by Monego et al *(54)*. In the case of fastness to light, or other fastness tests where an original color undergoes a change, there is something to be gained over visual examination by the use of the spectrophotometer to evaluate small color difference, because people may differ in their interpretation of the relative importance of strength and shade differences. Also, there are no standards for measuring color differences caused by light exposure, except the standard blue woolen fabrics, which may not undergo the same type of color change on fading as the samples under investigation. In the case of fastness to crocking, however, or other fastness tests where a white cloth becomes discolored, the problem is not one of the determination of a small change in the initial fabric but rather the determination of color added to white—that is, the color which has transferred from the colored fabric to the white cloth. For this purpose the AATCC color-transfer evaluation chart is so easy to use and tends to give such good agreement among different observers that there is probably little advantage in using a spectrophotometer for evaluation of crocking fastness.

If the spectrophotometer is to be used, it is recommended that the apparent amount of dye on the white fabric be evaluated by means of Formula 8. In cases where the crocked color differs from the original, as might well happen if one component of a formulation crocks more than the others, it would probably be better to use the tristimulus Y value of Formula 15.

14. SHADE MATCHING WITH IDENTICAL DYES——One problem is to produce a match for a standard color swatch with dyes similar to those that were present in the standard. As a practical example it may be desired to measure a fabric during the course of its dyeing to determine what dye additions should be made to bring it to shade by increasing the concentration of the dyes that are already present. This is really a matter of quantitative analysis for quantities of two or three dyes on the fabric. This application has been reported by Mersereau et al *(50)* and by Selling *(87)*.

For this purpose Formula 9 in the case of two dyes or Formula 10 in the case of three dyes is recommended.

15. BLENDING OF WOOL FIBERS——One problem in the blending of wool fibers is to predict the color which will result from a specified mixture. This has been reported by Mesereau et al *(50)* using the formula of Noechel et al *(60)*.

Another problem is predicting what fiber mixture will produce a specified color. In this connection we have the situation for which Duntley *(16)* has proposed a method of calculating a dye formula that is only approximate because it does not involve an additive function while Noechel et al *(60)* have given the additive function but have not proposed how to solve for the quantities of fiber lots needed. In the case of lots of wool of somewhat similar color, the method of Duntley works well. Unpublished data have indicated that a combination of the methods of Duntley and Noechel et al will lead to a prediction of a correct formulation made from wools of widely divergent color. In this unpublished method, successive approximations are made in a formula that combines the additive function of Noechel et al in the tristimulus simultaneous equations of Duntley. This is a technique which needs further elaboration in the future literature of spectrophotometry.

16. PERMANENT RECORDS OF COLOR STANDARDS——It has frequently been pointed out that the spectrophotometric curve of a color is a record which is not subject to fading or other deterioration *(2, 29, 31, 65, 91)*. However, except for a few Government specifications and specifications of atlases of color standards there seems to be no published record of any textile mill using the spectrophotometer for this purpose. Tristimulus values, given in Formula 15, are recommended for the numerical preservation of color standards.

17. DETERMINATION OF SHADE CHANGE FROM DAYLIGHT TO INCANDESCENT LIGHT——Dexter et al *(14)* have shown that by calculating tris-

timulus values under two conditions, namely incandescent light and daylight, and then noting if the colorimetric specification of the sample has changed relative to the standard, it is possible to determine whether or not a color change will occur when the illumination is changed from one to the other. This effect has also been studied by Godlove *(23)*, who has gone into the reason behind such changes.

18. SELECTION OF NEW DYES——One of the problems of a laboratory in a mill is to suggest what dyes should be stocked in order to match the shades that are required. Related to this is the problem of evaluation of a new dye when one is suggested to determine if it is a useful addition to the line, perhaps replacing an established dye. Two important factors are economy and fastness properties. A third important attribute of a dye is brightness. If a bright dye is available, it is possible to add black or some dull dye and attain the same hue with less brilliance. On the other hand, having a dull dye, there is no way of producing a brighter shade.

Reference *(2)*, Hardy *(29)* and Monego et al *(54)* have all suggested the use of a spectrophotometer to evaluate brightness of new dyes under consideration. They suggest only qualitative methods of test, which consist primarily of examining the spectrophotometric curves for nearly vertical portions and for high ratios of reflectance maximum to reflectance minimum. The theory behind this subject has been well discussed. MacAdam *(45)* has reported on the theoretical limits of any possible colors. Also, Vickerstaff *(100)* has reported on the brightness of present-day dyes. However, no method has been given wherein a single dyeing of a new dye can be evaluated to indicate just how good this dye is quantitatively in the production of the greatest number of shades.

A recommendation for qualitative analysis of brightness is ratio of dyeing absorbency indices (Formula 7) at high and low reflectances. Quantitative analyses should be carried out by the method of MacAdam *(47)* modified to apply to reflectance data rather than transmittance data. Formula 6 should be used instead of Formula 1 in this modification.

19. DETERMINATION OF EFFICIENCY OF DETERGENTS——Reference (2) suggested the use of the spectrophotometer to measure efficiency of detergent materials. Zussman *(106)* used the spectrophotometer in studying the action of sequestering agents in preventing metals from depositing on fabrics and thereby dulling dyed shades. He has also used the spectrophotometer to measure soil removal by measuring reflectance of the clean and soiled fabrics. Furry et al *(20)*, in studying the effectiveness of detergents in removing soil from a cotton and a wool fabric, used a change of light reflectance to indicate the soil-removing efficiency. Actually, this work was done with a Hunter small-color-difference meter rather than with a spectrophotometer, but the same scientific principles apply.

The recommended method for measuring the effect of soiling on white fabrics is a change in the tristimulus Y value (Formula 15) before and after laundering. It is believed that this is equivalent to the method that was used by Furry et al *(20)*. If colored fabrics were used in detergency studies, which is unlikely, it would probably be necessary to use Formula 16. If the detergent contains a fluorescent whitening agent a spectroradiometer must be used *(53)* rather than a spectrophotometer.

20. MEASUREMENT OF LEVELNESS OF FABRIC——Park *(65)* and Leonard et al *(40)* have both measured the apparent strength of different spots on a fabric and expressed unlevelness in terms of variation in apparent percent dyeing. The Northern New England Section *(62)* have expressed levelness in terms of integrating the area underneath the reflectance curves with a planimeter, but this does not appear to be an improved method of interpretation. Davidson et al *(12)* have measured unlevelness and expressed it in colorimetric specifications using trichromatic coefficients *(28)* and tristimulus value Y.

If the dyeing consists of only a single dye, the simplest method of expressing unlevelness is by the use of Formula 8 as was done by Leonard et al *(40)* and Park *(65)*. If the formulation consists of two or more dyes, then it is possible that this formula is not as good as expression in colorimetric terms. It is conceivable, for instance, that one dye will be fairly level over the entire fabric while a second dye will be unlevel. If the primary interest is in the dye concentration, as it might be if it is planned to substitute a more level dye for the one that is introducing the unlevelness, then the analysis of various spots for the amount of dyes present by Formula 9 would be indicated. If the purpose is merely to find variation of color, as it might be to evaluate the commercial acceptability of a fabric, and there is no interest in finding what dyes are causing the variation, then a variation of tristimulus values converted over to small color differences by Formula 16 is recommended.

21. EFFECT OF METALS ON DYES——Millson *(52)*, while studying wool dyeing, used spectrophotometric curves to show the effect of metals on the dyeings. Kienle et al *(37)* discussed the techniques of this measurement as specifically applied to the determination of the percent chromation of dye on wool. It is recommended that Formula 9 be used to give a quantitative value to the extent of metallization or that Formula 16 be used to give a measure of the visual color change introduced.

22. MEASUREMENT OF ACCURACY OF COLOR MATCH——It was early proposed by Hardy *(29)* that the spectrophotometer could be used for measuring small color differences and thereby for determining the accuracy of a color match. Color tolerances have been the subject of much study. One good review is the symposium on color tolerances held by the Intersociety Color Council *(30)*. Nickerson et al *(59)* have also presented a good review of tolerance formulas. Nickerson *(57)* summarized available information on small color difference formulas in 1944.

The formula which is most easily used in conjunction with tristimulus values is that of Adams *(1)*, which is very clearly explained by Nickerson *(58)*, who has worked out in detail a complete numerical example in her report.

There has been much discussion in the literature as to whether or not the spectrophotometer is as sensitive as the eye in the detection of small color differences. In this connection, it was pointed out by Park *(65)* that color variations in low-reflecting fabric samples and variations in hue of highly chromatic fabric samples were most difficult for the instrument to detect with a sensitivity comparable to visual evaluation. Skinkle et al *(90)* substantiated the fact that variations in hue are more easily seen by the eye than those of depth of color and, therefore, would be more difficult for the spectrophotometer to measure. Nutting *(63)* has pointed out that for differences in the high reflectance part of the spectrum the spectrophotometer is likely to be more sensitive than the eye.

The precision of the spectrophotometer has been discussed rather specifically by Hardy *(27)*, who states that the spectrophotometer has an over-all precision of about 0.1% of the measured reflectance value, and Davidson *(10)* states that the maximum error of a combination of the spectrophotometer and tristimulus integrator is of the order of 0.003 in terms of trichromatic coefficients in the comparison of metameric matches. In a summary statement concerning the accuracy of the tristimulus integrators, Davidson et al *(12)* state that the instrument appears to be equal to the eye in intensity on dark samples and better on light samples.

The exact size of the tolerance necessary for textiles has been the subject of considerable study. Nutting *(64)* was among

the first to investigate color differences among commercially acceptable textile samples. Judd *(33)* proposed a formula for the specification of uniform color tolerances for textiles and checked his formula with both the earlier work of Nutting *(64)* and additional data. Balinkin *(3)* reported the relationship between small color differences in the dye industry as expressed in adjectives and as expressed in Judd units. This correspondence is presented in Table III. MacAdam *(46)* has presented some ellipses on a chromaticity diagram, which represent least perceptible differences. His Figure 23 *(46)* shows that for some colors a difference of 0.0004 in trichromatic coefficient X is the least perceptible difference expressed as a standard deviation. Davidson *(9)*, in considering the MacAdam data in relation to textiles, thus using different test conditions than MacAdam, concluded that the proposed ellipses are more than one full difference. This would indicate that smaller color differences are of interest in the textile industry than those that were reported by MacAdam.

For measurement of accuracy of color match, it is recommended that small color differences be calculated with Formula 16. It is recommended that tolerances be determined for the individual problem in the individual mill rather than that a general tolerance value taken from the literature be applied without study. Then it should be determined by experiment whether or not the spectrophotometer has sufficient sensitivity to measure the tolerances of interest in any particular case.

23. DETERMINATION OF FASTNESS TO LIGHT——The spectrophotometer has been used in studying the various factors that are important in the determination of light fastness. For instance, Nordhammer *(61)* in his study of the conditions of temperature and humidity in the Fade-Ometer used reflectance curves of black and white samples in order to evaluate their usefulness in determining temperatures of samples in the Fade-Ometer. Also, it has been recommended in Reference (2) that the National Bureau of Standards paper standards be measured after fading in order to evaluate the equivalent hours of exposure which have been received by fabric samples simultaneously exposed.

In the evaluation of fastness, there have been several methods proposed. For instance, Lowry *(41)* has suggested that in order to specify the stability of colored filters to radiant energy, the spectrophotometric curves be obtained and the area between the transmittance curves of the filter before and after exposure be divided by the area underneath the transmittance curve of the unfaded filter in order to get a ratio that is a measure of stability. This may work for optical filters but it is not recommended for textile samples. Monego et al *(54)* have proposed that the strength or percent dyeing of the sample be determined before and after exposure and the loss in strength be a measure of fading. This, of course, is only a part of the fading picture because a shade change is often introduced which may be more important than any strength change. Monego et al *(54)* realized this and proposed the use of a ratio of reflectance at three wavelengths to indicate a shade change. Recently, however, there has been a tendency to use the small-color-difference formulas to express these results. Examples of this may be found in Luttringhaus et al *(43)*, Lyle et al *(44)* and Vickerstaff et al *(101)*. One of these *(44)* uses a Hunter reflectometer rather than a spectrophotometer in order to evaluate the color difference, but the optical principles behind these two measurements are the same, as explained by Nickerson *(58)*. Good examples of this application may be found in Davidson et al *(12)* and Godlove *(22)*. The only change suggested from the equation used by these authors is the use of 40 instead of 10 as the numerical value of the third factor in their formula.

The recommended procedure for measuring the amount of change in color introduced by light fading is to obtain the tristimulus X, Y and Z values of the same area on the fabric with the automatic tristimulus integrator before and after exposure, and then to substitute the chromatic-value equivalent of these values in the Adams' formula, which is Formula 16. An excellent numerical example of these calculations has been presented by Nickerson *(58)*, and it has been reported by Godlove *(22)* that these calculations require only 90 seconds each.

24. DETERMINATION OF FASTNESS TO GAS FADING——The work that has been done along this line by Ray and collaborators *(76, 77, 78, 79, 80)* has all been evaluated by means of a Hunter reflectometer and the corresponding small-color-difference formula. As an equivalent method of interpretation the spectrophotometer and Formula 16 are recommended.

25. DETERMINATION OF FASTNESS TO CARBONIZING——Monego et al *(54)* have reported the use of the spectrophotometer to evaluate fastness to carbonizing by measuring the reflectance before and after the carbonization process. So little work has been reported on this subject that it is difficult to recommend a procedure; however, it is believed that Formula 16 applied to measurements of the sample before and after carbonizing would probably measure satisfactorily any strength or shade difference.

26. THE EFFECT OF PROCESSING ON COLOR——Mersereau et al *(50)* have reported that a finishing operation changes the color of a fabric. For this application it is recommended that Formula 16 be used.

27. IDENTIFICATION OF DYES——The work of Stewart *(96)* is evidence of the widespread acceptance in other industries of the spectrophotometer to determine the identity of dyes in solution. This application has also been mentioned in reference *(2)* and Haller et al *(26)*. Stearns *(91)* pointed out that identification could be made either in solution or on fabrics. Successful identifications of dyes on fabrics have also been pointed out by Selling *(87)* and Simon *(89)*.

The recommended method of interpretation for this application in the case of solution data is to plot the curve with the T cam *(72)*. A comparison can then be made of the curve of the unknown with the curve of a standard dye and the curve shapes should be alike if the dyes are the same. The advantage of a T cam plot is that the curve shapes are the same even though the concentrations at which the solutions were prepared are somewhat different. The recommended method for reflectance data is to use the R cam *(73)*. The curve shapes of the same dye at different percent dyeings tends to remain constant and thereby facilitates identification. Differences in the curves in the region of high reflectance might well be caused by differences in the reflectances of the undyed fabrics.

28. EVALUATION OF BRIGHTNESS ——Davidson et al *(12)* have studied what the dyer means when he says that a sample is bright. They have found that this term correlates with the product of purity *(28)* and Y tristimulus value as determined from the spectrophotometer. Thus it is possible to give a numerical evaluation of brightness to any particular fabric. They report that they expect to modify this formula, but at present this is the best formula which has been proposed. It is recommended if brightness of a fabric is to be calculated. This may be of interest in evaluating the relative merits of different colors for noticeability. It might also be useful in the evaluation of the merit of new dyes (see application 18).

29. WHITENESS OF A WHITE——Reference *(2)* proposed that the spectrophotometer can evaluate the whiteness of a near white. Hardy *(29)* has pointed out how some of the theoretical considerations for producing an ideal white can be related to spectrophotometric data. However, the best discussions of whiteness are found in the literature of the pulp and

paper industry, in papers by Judd *(32, 34)* and Selling *(88)*.

It is suggested that calculations of numerical value of whiteness be made by substituting small color differences calculated with Formula 16 in the whiteness formula of Judd *(34)*. This proposal needs further elucidation in the future spectrophotometric literature.

30. DETERMINATION OF DYE COMBINATIONS FOR NEW SHADES——The term "color matching" is rather a loose term in that it denotes several different procedures. A new shade in a textile mill is ordinarily matched by using a combination of dyes which happen to be in stock, which have good fastness properties, or which are most economical. In general, the dyes selected are not the same as the dyes used in the submitted standard color swatch. Thus, the problem of color matching becomes one of producing a metameric match. Metameric matches have certain disadvantages. For instance, while they may match under one illuminant such as daylight, they may not match under another illuminant such as incandescent light. Because of these factors, examples of extreme metamerism are rather rare, but examples of slight metamerism are very common.

It has been implied that producing a metameric match with a spectrophotometer is easy. For instance, Johnston *(31)* says that the spectrophotometer allows the color to be matched by giving an accurate measurement of it. Also, Haller et al *(26)* state that color matching of finished fabrics is easily and accurately accomplished. Neither of these references, however, give detailed instructions as to how to proceed. Selling *(87)* has given some amazing demonstrations of color matching. When he begins to lecture, he asks for a sample from the audience, such as a colored area on a cover of a match book. He gives the color standard to an associate, who gets on a bicycle, pedals to his laboratory, measures the sample on a spectrophotometer, determines the necessary concentrations of three acid dyes to match it and returns to the lecture hall with the completed dyeing on wool before the end of the lecture. This is very impressive, but it is necessary to follow the rules as laid down by the lecturer. While you may specify the color to be matched, you do not have the privilege of naming the dyes which are to be used to produce the match. What is done, in effect, is to have previously measured many combinations of the three standard dyes—a blue, yellow and red. The sample to be matched is measured and, by comparison with tabulated data, the nearest of the previously dyed formulations is selected and reproduced for the meeting. Actually, not all of the dyeings have been made. Some have been calculated by an application of a formula very much like Formula 6. Nevertheless, the trial dyeings or the calculations have previously been carried out. Similarly Davidson et al *(12)* have proposed a method for the selection of a combination of three dyes to match an unknown color, but here again the previous formulations have either been experimentally dyed or calculated. These latter investigators plot data for the three standard dyes in the colorimetric terms x, y *(28)* and Y, but, actually, this plotting could be done on the basis of X, Y, Z or the Munsell color system or any other system. Simon *(89)* has stated that on worsted cloth he gets excellent results in shade matching but he does not describe the technique used in detail. Perhaps the method he uses is an approximate one which he has found useful in his particular mill, but not truly rigorous.

Park et al *(66)* have reported a method of producing metameric matches from any combination of dyes for any color, if such a match is possible, provided only that single standard curves of the components be available and Stearns *(91)* has reported some results made with these calculations. Unfortunately, however, these calculations require up to two hours for each individual match and, hence, the method is not yet practical for a textile mill.

31. EFFECT OF DYE ABSORPTION ON FLUORESCENT COLORS——Millson et al *(53)*, in their study of fluorescent dyes, measured the absorption curves of dyes in solution, inferred a similarity between these and the absorption curves on the fiber, and, from this, predicted certain effects that the absorption would have on the curve of the fluorescent color of the fabrics under investigation.

32. INFRARED REFLECTION——The importance of infrared reflectance in camouflage detection by photography has been reported by Stearns *(92, 93)*; the importance of infrared reflectance in the drying of textiles by infrared radiation has been pointed out by Preston et al *(75)* and Wilhelm et al *(102)*; the importance of infrared reflectance in the warmth of a garment has been studied by the Philadelphia Section (67) and by Greenler et al *(24)*.

SUMMARY OF APPLICATIONS

Table I summarizes the various recommendations of this article. Column 2 lists the applications of the spectrophotometer, column 3 gives the number of the formula recommended for the interpretation of the spectrophotometric data and column 4 gives one or two references which are recommended, usually because they describe in detail the suggested techniques.

SPECTROPHOTOMETRIC TECHNIQUES

THE SPECTROPHOTOMETRIC LABORATORY——In considering the possible applications discussed above, we have assumed that a textile mill has one room set aside containing a recent-model spectrophotometer, the necessary laboratory equipment, a literature library and a man devoting full time to the problem. By a

TABLE I
SUMMARY OF RECOMMENDED METHODS OF ANALYSIS

No	Application	Formula	Reference
1	Degree of Solubilization	2	2
2	Solubility of Dyes	3	104
3	Stability of Dyes	3	85
4	Testing Dyes for Strength	3	49
5	Dye Exhaustion from Dyebath	3	8
6	Dye on Fabric by Extraction	3	103
7	Exhaustion Rates	3	8
8	Rate of Reduction of Vat Dyes	4	84
9	Concentration of Dyes in Dye Bath	3, 4, 5	11
10	Selection of Base Stock for Dyeing	6	50
11	Exhaustion by Reflectance of Fabric	8	85
12	Evaluation of Stripping Agents	8	—
13	Evaluation of Fastness to Crocking	8	—
14	Shade Matching with Identical Dyes	9, 10	50
15	Blending of Wool Fibers	11	60
16	Permanent Color Records	15	91
17	Measuring Artificial-Light Effect	15	14
18	Selection of New Dyes	6, 15	47
19	Efficiency of Detergents	15	20
20	Levelness of Fabrics	8, 16	65
21	Effect of Metals on Dyes	9, 16	37, 52
22	Accuracy of Color Match	16	33, 58
23	Evaluation of Fastness to Light	16	22
24	Evaluation of Fastness to Gas Fading	16	76
25	Evaluation of Fastness to Carbonizing	16	—
26	Measuring Effect of Processing Wool	16	50
27	Identification of Dyes	—	91
28	Numerical Specification of Brightness	—	12
29	Whiteness of a Near White	—	34
30	Dye Formulas for New Shades	—	66
31	Effect of Absorption on Fluorescence	—	53
32	Infrared Reflectance	—	93

"recent-model spectrophotometer" is meant a General Electric spectrophotometer *(27, 31, 107)* having as auxiliary attachments a tristimulus integrator *(10)*, and at least three of the developments introduced by the Calco laboratories, namely, a depolarizer *(6)*, an R cam *(73)*, and a T cam *(72)*. These attachments represent some of the improvements to the original model General Electric instrument which are of greatest interest to the textile man. It might be mentioned that not all the design changes in the evolution to the present instrument have been an improvement for textile use. For instance, the change from 0° incidence to 4° incidence of light on the sample, which was done to accommodate measurements of glossy samples of paints and plastics, introduced an undesirable geometrical azimuth effect in the measurement of some textile samples, such as pile fabrics, which, in general, have the pile not perpendicular to the backing.

It is recommended that the auxiliary equipment listed above be included with the basic instrument in order to simplify the interpretation of data. The R and T cams are a convenience comparable to the convenience of a slide rule to a man who has to carry out multiplication and division of many numbers. The depolarizer is a convenience, which eliminates in some cases the necessity of running a fabric in two positions and then averaging the data before the curves are used for calculation. The tristimulus integrator performs a calculation that is rather tedious to make by other methods.

By ordinary laboratory equipment is meant an analytical balance, volumetric pipets and flasks, common chemical reagents, such as those necessary to adjust the pH and to aid in the solution of dyes, and the usual laboratory facilities, such as distilled water, solvents, hood, electrical hot plates, and stirrers. There are also special spectrophotometric supplies, such as plotting paper, absorption cells, special holders for mounting reflectance samples, and magnesium metal, which is burned to magnesium oxide in preparing reflectance standards.

A minimum library, which should be available for consultation, might consist of the following books:

1. *Introduction to Color* by R M Evans, John Wiley & Sons (1948).
2. *Handbook of Colorimetry* by A C Hardy, Technology Press, Cambridge, Mass (1936).
3. *Analytical Absorption Spectroscopy* by M G Mellon, John Wiley & Sons (1950).
4. *Munsell Book of Color*, Munsell Color Company, Baltimore, Maryland (1942).
5. *The Measurement of Color*, W D Wright, Adam Hilger (1944).
6. The last ten years of the *American Dyestuff Reporter*.
7. The last ten years of *The Journal of the Optical Society of America*.
8. *Standard Color Card of America* by Textile Color Card Association of the United States, 9th Edition, New York (1941).

The contribution of a man responsible for operating the laboratory to the success of the program will depend only partly on his formal education. A recommended education is the equivalent of a bachelor's degree in physics. This specific training is, of course, not necessary. There are many young men in a dye house, who, though they lack the formal education, because of their experience with dyes and dyeing, might even be more valuable in spectrophotometry. The recommendation is made to indicate only the general character of a man that should fill this job. It is advisable that he spend full time because the science is a reasonably complicated one and is unlikely to receive proper attention unless this is the case.

SOLUTION PREPARATION AND MEASUREMENT —— One fundamental technique which is common to many applications of the spectrophotometer is based on the measurement of the transmission of light by a glass absorption cell filled with a dissolved dye. It is recommended that anyone who is undertaking this kind of work should be thoroughly familiar with what has been given in pages 313 to 341 of Mellon *(48)*. This reference points out some of the sources of error in solution measurements and recommends that two tests be applied to find whether a particular technique is satisfactory. These two tests are as follows: (1) determine whether the same results can be obtained from one day to another, and (2) determine whether the dye solution is stable for a period of 24 hours. If the solution measurement fails in either of these two respects, then an attempt should be made to improve the technique. Reference can be made to the various solution effects, which are enumerated in Mellon, to find the cause of the trouble.

Table II, which draws liberally upon information contained in articles by Simon *(89)* and Mersereau et al *(49)*, summarizes recommended solution conditions for the various types of dyes.

A good discussion of the measurement of dye solutions will be found in Mellon *(48)*, particularly on pages 78 and 101.

FIBER PREPARATION AND MEASUREMENT——The dyeing of fabrics or textile fibers in other physical forms needs no comment. The measurement of such samples by reflected light, however, is quite a different matter. The first point which needs stressing is that best results are attained with a spectrophotometer if the standard fabric and the sample fabric are identical. A common problem is to determine whether two samples look alike or look different in color. One might expect that a standard, such as a plastic button, could be placed in the spectrophotometer, measured, and later a piece of textile fabric could be placed in the spectrophotometer and measured. Then, if the curves produced by these two articles were the same, the colors would be the same and they would be a color match. It is a well-established fact, however, that the color of an object will vary, depending upon how it is illuminated and viewed. The spectrophotometer has a very special way of illuminating and viewing. The light strikes the sample very nearly perpendicularly to the surface, and then all of the light which is scattered in all directions is gathered together and viewed by the photocell. If it were possible for the human eye to duplicate this, then the eye would see samples the same way that the spectrophotometer does. This could be approximated by crawling underneath a spectrophotometer and placing your eye in the position where the photocell of the instrument is normally located. This, however, is not the viewing condition that is ordinarily used by textile dyers in judging closeness of match. Consequently, identity of spectrophotometric curves is no assurance of equivalent color appearance of two such widely divergent materials. This has been previously pointed

TABLE II

RECOMMENDED SOLUTION CONDITIONS

Type of Dye	*Solvent*
Acid	Water at pH 5
Basic	Water at pH 3
Chrome	Water at pH 9
Directs	Water at pH 7 containing PEOC**
Acetate	Acetone
Vats*	Water containing 1% NaOH, 1.2% $Na_2S_2O_4$, and 1% PEOC**
Sulfurs	Water containing Na_2S and Na_2CO_3
Azoic Bases*	Coupled to R-salt in water
Azoic Naphthols*	Coupled with diazotized sulfanilic acid and dissolved in 50% alcohol

Notes: *See Simon (*89*) for further details.
**PEOC is polyethylene oxide condensate as described by Taylor et al (97).

out by Park *(65)*. A comparison of wool and rayon is not quite so bad as a comparison of wool with a plastic button. A comparison of wool gabardine with wool herringbone twill is even less erroneous. Thus, as the standard and sample approach more and more nearly to each other in nature, the validity of the color comparison improves, but even the difference between a decatized and a steamed woolen flannel will introduce a color difference which is of the order of magnitude of an ordinary commercial tolerance.

When the problem is to identify and determine the quantity of dye on a fabric, it is necessary that the unknown dye be on the same type of material as the known or standard dye. It is well known that the amount of dye on one fabric might look lighter or darker than the same amount of dye on another fabric. Fothergill *(19)* has constructed a nomograph to help in the dyeing of fine and coarse rayon to the same shade. In spite of such literature information, this fundamental fact is sometimes overlooked in spectrophotometric work.

Even in cases where the identical type of textile sample is used for the standard and the unknown, there still are problems of conditioning the sample and measuring it reproducibly. This problem is so important in precise measurements that a committee has been set up by the Inter-society Color Council to study this very effect. Some of the important factors which have been listed in reference *(2)* and Stearns *(94)* are the following:

a. *Opacity*—The sample should be opaque. This can sometimes be accomplished by putting several layers of fabric behind each other, but this becomes very complex in the case of netting, knit goods and similar materials.

b. *Proximity of sample to integrating sphere*—A surprisingly large difference in apparent reflectance occurs between a sample which is protruding into the integrating sphere and one which is slightly, say 1/10 inch, removed from the sphere.

c. *Azimuth Effect*—Very often a sample will give a different reflectance curve depending upon whether the weave in the sample is horizontal or vertical, even though the same area of the fabric is exposed to the light beam for the measurement. Without a depolarizer, this effect is very marked on many textile fabrics because of an effect which is associated with the polarization of light. Even with a depolarizer in the spectrophotometer, the results still may depend upon the angle because of a geometrical effect.

d. *Fabric Levelness*—Of course, there are the usual difficulties in selecting an area on the sample to overcome any unlevelness or two-sidedness.

e. *Color Instability*—There are other effects which are well known to the dyer, such as irradiation or phototropism and moisture regain, which affect the spectrophotometric curve as much as the visual appearance.

f. *Fluorescence* — Fluorescent samples cannot be measured properly with the presently available General Electric spectrophotometer. It should be possible to measure fluorescent samples with the General Electric spectroradiometer *(74)*, provided a standard light source is used which duplicates daylight both in the visual and in the ultraviolet region. This, however, is a subject worthy of discussion by itself.

A standard method of mounting and measuring samples cannot be recommended here. It can only be emphasized that this is one of the big problems and that it will occupy much of the time of a man engaged in spectrophotometry. This does not mean, however, that investigators will fail to get data on reflectance samples which will be useful in their own mills.

IMPORTANT FORMULAS

Once a spectrophotometric curve has been obtained, the next problem is that of interpretation. The following sixteen formulas are the ones that are recommended to interpret the data for most of the applications which were given above:

DEFINITION OF SYMBOLS AND SUBSCRIPTS USED IN FORMULAS

Symbols

$A = \log_{10}(1/T)$
$A' = [(1-R)^2/(2R)]$—F
$A'' = (100\text{-}100R)/(15R + 0.85)$
B = cell length (centimeters)
C = concentration (grams per liter)
C' = concentration (percent dyeing)
C'' = fraction of total blend
D = denominator defined with formula 5
D' = denominator defined with formula 10
D'' = denominator defined with formula 14
ΔE = small color difference (Judd units)
$F = (1-R_f)^2/(2R_f)$
$H = (C_aK_a + C_bK_b + \ldots\ldots)$
$H' = (F + C'_aK'_a + C'_bK'_b + \ldots\ldots)$
$H'' = C''_aK''_a + C''_bK''_b + \ldots\ldots)$
I = spectral irradiance of light source
K = absorbency index (1000cm² per gram)
K' = dyeing absorbency index (arbitrary units)
K'' = fiber-blend index (arbitrary units)
R = reflectance (unit)
T = transmittancy (unit)
V_x = chromatic value of X
V_y = chromatic value of Y
V_z = chromatic value of Z
X = tristimulus value X
$\bar{x}$ = X tristimulus specification of a spectral color by the standard observer.
Y = tristimulus value Y
$\bar{y}$ = Y tristimulus specification of a spectral color by the standard observer
Z = tristimulus value Z
$\bar{z}$ = Z tristimulus specification of a spectral color by the standard observer
$d\lambda$ = with respect to wavelength
Δ = indicates the numerical difference between two quantities.

Subscripts

a = dye "a"
b = dye "b"
c = dye "c"
f = mock dyeing (fabric put through dyeing process with no dye added)
m = test sample
am = dye "a" in sample "m"
1 = wavelength "1" or sample "1"
2 = wavelength "2" or sample "2"
3 = wavelength "3" or sample "3"

FORMULAS

1. Formula for calculating the transmittancy of a mixture of dyes in solution at any one wavelength:

$$T_{m1} = 10^{-H_1B_m}$$

2. Formula for determining the absorbency index at any one wavelength of a single dye in solution:

$$K_{a1} = A_{a1}/(C_aB_a)$$

3. Formula for determining the concentration of a dye "a" in a solution containing only one dye:

$$C_{am} = A_{m1}/(K_{a1}B_m)$$

4. Formula for determining the concentration of dye "a" in a solution containing two dyes "a" and "b":

$$C_{am} = \left(\frac{K_{b2}}{K_{a1}\,K_{b2} - K_{a2}\,K_{b1}}\right)\frac{A_{m1}}{B_m} - \left(\frac{K_{b1}}{K_{b1}\,K_{b2} - K_{a2}\,K_{b1}}\right)\frac{A_{m2}}{B_m}$$

5. Formula for determining the concentration of dye "a" in a solution containing three dyes "a", "b", and "c":

$$C_{am} = \left(\frac{K_{b2}\,K_{c3} - K_{c2}\,K_{b3}}{D}\right)\frac{A_{m1}}{B_m} + \left(\frac{K_{b3}\,K_{c1} - K_{b1}\,K_{c3}}{D}\right)\frac{A_{m2}}{B_m} + \left(\frac{K_{b1}\,K_{c2} - K_{b2}\,K_{c1}}{D}\right)\frac{A_{m3}}{B_m}$$

$$D = K_{a1}\,(K_{b2}\,K_{c3} - K_{b3}\,K_{c2}) + K_{b1}\,(K_{a3}\,K_{c2} - K_{a2}\,K_{c3}) + K_{c1}\,(K_{a2}\,K_{b3} - K_{a3}\,K_{b2})$$

6. Formula for calculating the reflectance of a mixture of dyes on a fabric at any one wavelength. (In this and the following formulas, the word fabric is used to identify any reflectance sample; for instance, raw stock, yarn, or cloth):

$$R_{m1} = 1 + H'_1 - (H'_1)^2 + 2H'_1)^{1/2}$$

7. Formula for determining the dyeing-absorbency index at any one wavelength of a single dye on a fabric:

$$K'_{a1} = A'_{a1}/C'_a$$

8. Formula for determining the concentration of a dye "a" on a fabric dyed with only one dye:

$$C'_{am} = A'_{m1}/K'_{a1}$$

9. Formula for determining the concentration of dye "a" on a fabric dyed with a mixture of two dyes "a" and "b":

$$C'_{am} = \left(\frac{K'_{b2}}{(K'_{a1}\ K'_{b2} - K'_{a2}\ K'_{b1})}\right) A'_{m1} - \left(\frac{K'_{b2}}{(K'_{a1}\ K'_{b2} - K'_{a2}\ K'_{b1})}\right) A'_{m2}$$

10. Formula for determining the concentration of dye "a" on a fabric dyed with a mixture of three dyes "a", "b", and "c":

$$C'_{am} = \left(\frac{K'_{b2}\ K'_{c3} - K'_{c2}\ K'_{b3}}{D'}\right) A'_{m1} + \left(\frac{K'_{b3}\ K'_{c1} - K'_{b1}\ K'_{c3}}{D'}\right) A'_{m2} + \left(\frac{K'_{b1}\ K'_{c2} - K'_{b2}\ K'_{c1}}{D'}\right) A'_{m3}$$

$$D' = K'_{a1}\ (K'_{b2}\ K'_{c3} - K'_{b3}\ K'_{c2}) + K'_{b1}\ (K'_{a3}\ K'_{c2} - K'_{a2}\ K'_{c3}) + K'_{c1}\ (K'_{a2}\ K'_{b3} - K'_{a3}\ K'_{b2})$$

11. Formula for determining the reflectance of a fabric made by blending together several fibers:

$$100\ R_{m1} = \frac{100 - 0.85\ H''_1}{1 + 0.15\ H''_1}$$

12. Formula for determining the fiber-blend index at any one wavelength of a single fabric:

$$K''_{a1} = A''_{a1}$$

13. Formula for determining the fraction of component "a" in a mixture of fibers containing two components "a" and "b":

$$C''_{am} = \left(\frac{1}{(K''_{a1} - K''_{b1})}\right) A''_{m1} - \left(\frac{K''_{b1}}{(K''_{a1} - K''_{b1})}\right)$$

14. Formula for determining the fraction of component "a" in a mixture of fibers containing three components "a", "b", and "c":

$$C''_a = \left(\frac{K''_{b2} - K''_{c2}}{D''}\right) A''_{m1} - \left(\frac{K''_{b1} - K''_{c1}}{D''}\right) A''_{m2} + \left(\frac{K''_{b1}\ K''_{c2} - K''_{b2}\ K''_{c1}}{D''}\right)$$

$$D'' = (K''_{a1} - K''_{c1})\ (K''_{b2} - K''_{c2}) - (K''_{a2} - K''_{c2})\ (K''_{b1} - K''_{c1})$$

15. Formulas for determining the tristimulus values of a fabric:

$$X = \Sigma \bar{x} I R d\lambda$$
$$Y = \Sigma \bar{y} I R d\lambda$$
$$Z = \Sigma \bar{z} I R d\lambda$$

16. Formula for calculating the color difference between two fabrics differing slightly in color:

$$\Delta E = 40 \left\{ (0.23\ \Delta\ V_y)^2 + [\Delta\ (V_x - V_y)]^2 + [0.4\ \Delta\ (V_z - V_y)]^2 \right\}^{1/2}$$

COMMENTS ON FORMULAS

Formula 1 is the fundamental formula for calculating the transmittancy of a mixture of dyes in solution. It is the Beer-Lambert law modified to account for several dyes in one solution. Very seldom is it desired to calculate the transmittancy of a solution, but this is the fundamental law from which Formulae 2, 3, 4 and 5 are derived, and, because of this, it is very important. In order to understand the derivation of this formula, one is referred to pages 88-95 of Mellon *(48)*. It is well known that this law does not strictly reflect the behavior of all dyes. For instance, see pages 319 and 373 of Mellon *(48)* which discusses two ways in which this law can fail. However, it so well states the behavior of most dyes and combinations of dyes, that it is very useful in practice.

Formula 2 is merely Formula 1 rearranged for convenience in solving for the absorbency index. The absorbency index must be found for individual dyes of known strength which are to be used as standards in the calculation of other solutions. The absorbency indices, for instance, must be substituted in Formulas 3, 4 and 5 in order to solve for concentration of dye. The value "A" in this equation is equal to $\log_{10}(1/T)$. In working with this equation and also with Formulae 3, 4 and 5, it may be found convenient to use a table giving values for A for various values of T. Such a table has been published by Brode *(5)* on page 616 and in Calco Technical Bulletin No 820.

Formula 3 is a convenient form for solving the concentration of one component. It will be noted that the value of K, which is based on a measurement of the standard dye, need be calculated only once.

Formula 4 permits one to solve for quantity of dye "a" in a mixture of dyes "a" and "b". Once the quantity of "a" has been determined, if it is also desired to determine the quantity of dye "b", the same equation may be used a second time. "a" and "b" should designate different dyes the second time. It should be noted that the analysis for two dyes may be made either from measurements of one solution at two wavelengths or measurements of two solutions, provided the two solutions are suitably related. For a further discussion of this, one should refer to page 388 of Mellon *(48)*. It should also be noted that the values inside of the parentheses in Formula 4, which are based on measurements of the standard dyes, need be evaluated only once. Henceforth the quantities in the parentheses are numerical constants.

Formula 5 shows how to calculate the concentration of dye "a" in a mixture of three dyes. In order to solve for concentration of dye "b", Formula 5 is used a second time but the subscripts "a", "b", and "c" should be used to designate different dyes than they designated in the first calculation. It will be noted that the quantities in the parentheses of Formula 5 are calculated only once from measurements of the standard dyes, and then are numerical coefficients.

Formula 6 is known as the Kubelka and Munk equation *(38)*. Pineo *(73)* was the first to suggest and design an improved spectrophotometer which plotted data in a form related to this equation. Unfortunately, he never elucidated the formula outside of the patent literature, which does not make a convenient reference. For an understanding of this formula, therefore, one must refer to reference *(2)*, Mersereau *(50)*, and Stearns *(95)*. It is well known that Formula 6 is not strictly correct. There should be additional constants in the equation to account for particular fabrics as discussed by Stearns *(95)*; or, for a more generalized sample, an 8-constant equation of Duntley *(17)* may be used. However, equation 6 is so nearly true that it is very useful in practice. The only place it begins to fail badly is at low reflectances. The exact reflectance where it fails varies with different fabrics, somewhere in the neighborhood of 5 per cent

reflectance for rayon fabrics and 2 per cent reflectance for wool fabrics.

Formula 7 is Formula 6 rewritten in convenient form for calculation of dyeing-absorbency indices. These dyeing-absorbency indices are of little interest in themselves but are needed for substitution in Formulae 8, 9 and 10 in order to solve for per cent dyeing. In connection with the use of this equation and Formulas 8, 9 and 10, it is convenient to have a table relating reflectance to $(1-R)^2/2R$. Such tables have been presented by Duncan *(15)* (as reciprocals), Laughlin *(39)* and in Calco Technical Bulletin No 820.

Formula 8 is Formula 6 rewritten in convenient form for calculation of per cent dyeing of a single dye on a fabric. It will be noted that the value of K′ need be determined only once, from measurement of a standard dyeing, and it then becomes a constant numerical coefficient.

Formula 9 is used for the determination of the concentration of a dye in a mixture of two dyes on a fabric. If it is desired to solve for the per cent dyeing of the second dye also, then the subscripts "a" and "b" should be used to designate different dyes and the formula applied a second time. It should be noted that the quantities inside the parentheses, based upon measurements of the standard dyeing of the individual components, need be determined only once. They then become numerical coefficients.

Formula 10 permits one to calculate the percent dyeing of one dye in a mixture of three dyes on a fabric. In order to solve for the second and third dye present, the subscripts "a", "b", and "c" should be used to designate different dyes and the equation applied a second and third time. It should be noted that the quantities inside the parentheses are determined once from measurements of standard dyeings of individual dyes; they then become numerical coefficients.

Formula 11 is the fundamental equation relating the reflectance of a fabric to the individual fibers from which it is made. For an understanding of this formula and its derivation, reference should be made to Noechel et al *(60)*. It is known that Formula 11 is not strictly correct for all fibers. If the fibers become very small or very large in diameter, it will be necessary to change the numerical value of the coefficients of H″. The formula, as given, works well for ordinary mixtures of wool and will be a first approximation to mixtures of other fibers.

Formula 12 is merely Formula 11 rewritten in convenient form for determining the fiber-blend index of a fabric. By itself this is not often of interest, but it is needed to substitute for the K″ value in Formulae 13 and 14.

Formula 13 indicates the calculation of the fraction "a" present in a mixture of two fibers. Since the sum of the fractions of each of the two fibers must necessarily add up to 1, the fraction of the second component is determined merely by subtracting from 1 the fraction of "a" present. It should be noted that the quantities inside the parentheses need be determined only once from measurements of the standard fibers. This equation may then be used until the homogeneous lot of fibers has been completely processed by the mill.

Formula 14 indicates the calculation of the fraction of fibers "a" present in a mixture of three fibers. In order to solve for a second fiber concentration, the subscripts "a", "b" and "c" should be used to designate different dye fibers and the equation applied again. In order to calculate the concentration of the third component, it is only necessary to subtract the fractions of the first two components from 1 since the sum of the three fractions present must necessarily add up to 1. It should be noted that the quantities inside the parentheses are determined only once, calculated from measurements of the standard fibers. The same numerical coefficients may then be used until the entire lot of homogeneous fibers has been processed by the mill.

Formula 15 shows the calculation of tristimulus values. For an understanding of these equations one is referred to page 515 of Mellon *(48)*. It is recommended that these equations be calculated by the automatic tristimulus integrator (10); but if this is not available, then the methods outlined in Hardy *(28)* must be used. It is well known that these formulae are not strictly correct, and there is some talk of revision as discussed by Judd *(35)*. Nevertheless, they are nearly enough correct to be extremely useful in practice.

Formula 16 is the recommended formula for calculating small color differences. For an understanding of this equation and its derivation, one is referred to articles by Nickerson *(57, 58)*. In using this formula, it is necessary to convert the tristimulus values to chromatic values. As this conversion is not based on a mathematical formula it is therefore necessary to refer to tables that have been determined on an empirical basis. Tables for this purpose have been published by Nickerson *(58)*. While this equation looks rather formidable, with a little practice it can be worked out quickly. In fact, Godlove *(22)* has reported that the total time necessary for the calculation of a small color difference by this formula, once the tristimulus data have been obtained, is 90 seconds. It is well known that this formula is not strictly correct. One improvement has been suggested by Saunderson et al *(86)*; however, it is nearly enough correct for practical purposes.

It may seem strange to take a formula proposed by Adams and designate the numerical values so obtained as Judd units as has been done in the table of "Definitions of Symbols and Subscripts Used in Formulas". It has been demonstrated by Nickerson *(57)* that the results obtained with six small-color-difference formulas which have been proposed at various times are all more or less equivalent. Judd was one of the first to propose such a formula and to suggest that the units be named. His original proposal was to call them NBS units after the National Bureau of Standards, but it seems to the writer quite appropriate to call them Judd units. The relation between Judd units and "average" textile terminology used in describing a color difference has been reported by Balinkin *(3)*. Judd *(33)* gives a similar comparison.

TABLE III

Textile Terms	*Judd Units*
Trace	0.0-0.5
Slight	0.5-1.5
Noticeable	1.5-3.0
Appreciable	3.0-6.0
Much	6.0-12.0
Very much	More than 12.0

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30th NATIONAL CONVENTION

PERSONNEL SERVICE AT CONVENTION

For the purpose of introducing members to prospective employers, Personnel Service will operate, without charge, from Wednesday afternoon, October 17, through Friday morning, October 19, at the New York Convention.

Every member expecting to use this Service in seeking employment is requested to write in advance to Dr H C Chapin, Secretary, AATCC, Box 28, Lowell, Massachusetts, for two blanks on which to state his qualifications and desires. For attachment to these, two photographs measuring about 2 x 2½ inches are desirable.

Employers registering with the Service will be permitted to consult these records, and will be assisted in arranging interviews between 2:00 pm and 5:00 pm on Wednesday; between 9:00 am and noon, and 1:00 pm to 5:00 pm on Thursday; and between 9:00 am and noon on Friday. Representatives of educational institutions also are invited to register for the purpose of answering inquiries about their students.

HOTEL STATLER

NEW YORK, N Y

OCTOBER 17-18-19

AUSPICES OF

NEW YORK SECTION

EXPOSITION

UNDER THE MANAGEMENT

OF

CAMPBELL-FAIRBANKS, INC.

NEWS

Three Views of the Renovated Arnold, Hoffman Building Laboratory Facilities

(Above)—Auxiliary Dye Lab

(Right)—Two Views of the Research Laboratory

• Arnold, Hoffman Completes Providence Alterations

An open house celebration on August 2 marked the formal opening of Arnold, Hoffman & Company's newly renovated office and laboratory building at 55 Canal St, Providence, R I.

Originally the old structure, which has served as Arnold, Hoffman's home for 105 years on Market Square, was two separate buildings; now, one complete building houses everything. Changes include a new street floor front, new windows and brick walls, asphalt tile or carpeting (in place of old-fashioned wide board), refinished masonry walls, and the addition of restful colors to offices and laboratories.

Whereas the old building furnished storage and shipping facilities, the renovated structure is taken over "almost completely" by offices and laboratories. The ground floor plan includes a reception room, the president's office, administrative offices, accounting departments, filing and mailing operations, receiving department and Providence sales offices and purchasing department. Other offices and department heads are on the second floor, and at the rear of this floor are located the sales service laboratory and other laboratory facilities. Except for the library and a supply storage room, the third floor is devoted to research and development laboratories, and a new cafeteria for the staff which includes a combination sink, refrigerator and stove. Included in the equipment innovations is new glass-blowing equipment, which makes possible the production of some equipment on the spot.

The laboratory set-up is now said to be one of the most complete to be found in a company the size of Arnold, Hoffman.

• PC&C Completes Major Unit

Completion of the first major unit of the new central research laboratories of the Pittsburgh Coke & Chemical Company at Neville Island, Pa, was announced on August 2. The new installation is said to more than double PC&C's available laboratory space and to centralize a number of research groups.

R M Marshall, president, pointed out that the research needs of the company's new fine chemicals division, which is expected to be in operation by the end of the year, were of immediate importance and that further expansion, primarily in the field of synthetic organic chemicals, is indicated in the future.

The new laboratories are unique in that they are constructed primarily of Pittsburgh Coke & Chemical products.

• Heyden Signs for Entire Floor at 342 Madison Ave

Heyden Chemical Corporation has signed a lease for the entire 16th floor in the Canadian Pacific Building, 342 Madison Ave, New York, N Y, through Herbert McLean Purdy Management Corporation, brokers, for occupancy in early 1952, it is learned.

Heyden reportedly plans to use the new space for the executive offices, which have been located at 393 Seventh Avenue since 1944, and also as headquarters for the sales offices of its subsidiary, the American Plastics Corporation. The new offices will also be used as headquarters for the Heyden Market Development, Technical Sales, and Advertising departments now located at Heyden's Garfield (N J) Division and the Heyden Medical Department.

Meanwhile, Heyden has completed plans for construction of a series of new laboratory units at its Chemical Research Division (also in Garfield), which will reportedly increase research facilities by 30 percent. The first new laboratory unit, now under construction, is scheduled for completion in the last quarter of 1951.

Tennessee Eastman Company's Lodi distribution center viewed from the top of the newly constructed tank farm. Building in right background houses sales offices, dyestuff service laboratory and a warehouse for drummed chemicals and dyes.

• Expansion of N J Distribution Center Announced

The Lodi, N J, distribution center of the Tennessee Eastman Company Division, Eastman Kodak Company, has been expanded to handle virtually the company's entire line of industrial chemicals and dyestuffs. Formerly the Lodi establishment included sales offices and a service laboratory for dyestuffs in addition to warehouse space for drummed chemicals and dyes.

In an effort to provide more complete service in southern New England and the Middle Atlantic areas, warehouse space has been doubled and a tank farm constructed, which includes tank car unloading facilities and drum and tank wagon loading stations.

• Wyandotte Names Midwest Distributors

Walter L Rippeteau, manager of organic chemical sales, Wyandotte Chemicals Corporation, has announced the appointment of the Solvents & Chemicals Group as distributors of Wyandotte's synthetic detergents and promoters for their detergents in the Midwest. The Group, which is comprised of 12 industrial companies, will handle distribution of the various grades of Kreelon, Carbose, etc. Wyandotte research facilities, with respect to detergent applications and compounding problems, are available through all distributor outlets.

All grades of the above products reportedly are available from Buffalo Solvents & Chemicals Corp, Buffalo 7, N Y; Central Solvents & Chemicals Co, Chicago 12, Ill; Amsco Solvents & Chemicals Co, Cincinnati 29, O; Western Solvents & Chemicals Co, Detroit 11, Mich and Toledo, O; Ohio Solvents & Chemicals Co, Cleveland 11, O; Hoosier Solvents & Chemicals Corp, Indianapolis 22, Ind and Fort Wayne 1, Ind; Wolverine Solvents & Chemicals Co, Grand Rapids 9, Mich; Texas Solvents and Chemicals Co, Houston 15, Texas; Wisconsin Solvents & Chemicals Corp, Milwaukee 14, Wisc; and Missouri Solvents & Chemicals Co, St Louis, Mo.

• Construction of New GAF Plant to Begin Shortly

Construction of facilities devoted mainly to the manufacture of detergents is scheduled to begin shortly in Kentucky with the locating of a new plant of the General Aniline & Film Corporation at Doe Run in Meade County. Through agreement with Mathieson Hydrocarbon Chemical Corp, which has recently completed a plant at Doe Run, General Aniline has acquired the adjacent acreage on which the plant will be built as well as a raw materials supply. The new plant reportedly will augment the Company's detergent production at Grasselli, N J.

The site at Doe Run lies along the Ohio River about 25 miles from Louisville and consists of approximately 100 acres. The new facility reportedly will embody a continuous processing operation as opposed to the traditional batch method.

Engineering estimates call for completion of construction in about 18 months.

• White Italian Bentonite Again Available

White Italian Bentonite, a colloidal clay of high whiteness and purity used as an emulsifying-, spreading-, suspending-, plasticizing-, absorbing-, dehydrating- and sizing agent, is again being imported by Whittaker, Clark & Daniels, Inc, 260 W Broadway, New York 13, N Y after several years on the scarce list. The company, exclusive distributors for the product, will handle both the high gel and the low gel types, it is reported.

W C & D, Inc, will continue to represent the American Colloid Company as their Eastern Distributors of "Volclay" and "Panther Creek" Bentonites. Volclay, a Western U S bentonite mined in the Black Hills of South Dakota, is prepared in powdered and granular forms for commercial use. Panther Creek, produced in Mississippi, differs from Volclay in that it is practically nongel forming and nonsuspending in water. Both are gray in color and have advantages in applications where color and high purity are not factors.

More complete information on either White Italian Bentonite, Volclay, or Panther Creek will be furnished by Whittaker, Clark & Daniels, Inc.

• French Specialists Study U S Productivity Methods

Thirteen dyeing and finishing specialists from the French textile industry arrived in the United States last month for a six-week study of American productivity methods, the third such team to be brought here under the technical assistance program of the Economic Cooperation Administration. The other two studied cotton spinning and textile marketing.

Since the team's arrival in New York August 1, visits have been made to the headquarters of the Textile Workers Union of America (CIO) in New York; the U S Finishing Co, Norwich, Conn; Mt Hope Finishing Co, North Dighton, Mass; Providence Dyeing, Bleaching and Calendering Co, Providence, R I; Dyestuffs Division, E I du Pont de Nemours & Co, Inc, Providence, R I; Hartsville Printing & Dye Works, Hartsville, S C; Sales-Biltmore Finishing Co, Biltmore, N C; Fairforest Finishing Co, Spartanburg, S C and the Appleton Bleachery, Anderson, S C.

Dr R F Poole, president of Clemson College and Dr H M Brown, dean of that institution's Textile School, welcomed the team to two five-day seminars, conducted by leaders of industry, state

government and the faculty. Speakers at the seminars included the following:

Nelson Jackson of Jackson and Jackson, Inc, converters; John T Wigington, director, Division of Technical Service, American Cotton Manufacturers Institute, Inc; Prof Frank A Burtner; W Fred Ponder, State Commissioner of Labor; John R Hopkins, technical representative of the Becco Sales Corp; C C Cayce, assistant Southern manager, General Dyestuff Corp; Clifford B Denison, public relations director, Dunean Mills; J M Cook, chief, Clemson Laboratory, U S Government Production and Marketing Administration; W B DePass, vice president, and F V Tribbel, Southern manager, Textile Color Division, Interchemical Corp; Dr Norman Armitage, Deering-Milliken Research Trust, Pendleton, S C; N R Vieira, technical representative, E I du Pont de Nemours Co, Inc, Dyestuff Division; H M Messenger, engineering representative, Taylor Instrument Co; H D Terhune, technical representative, du Pont; L C Tolleson, maintenance engineer, Union Bleachery, Greenville, S C; H B Carlisle personnel manager, Pacific Mills, Lyman, S C; and Kenneth H Barnard manager, Textile Resin Department, American Cyanamid Co.

The itinerary of the team for the month of September is as follows:

September 3-8, Clemson: Southern Bleachery, Taylors, S C; Union Bleachery, Greenville, S C; Excelsior Mills, Pendleton, S C.

September 9-13, Washington: Meetings with American Council on Education, U S Department of Labor, National Planning Association, ECA, United Textile Workers of America (AFL).

September 14-15, New York and departure for France.

• Order M-71 Amended

Order M-71 has been amended by the National Production Authority to liberalize priorities assistance to scientific and technical laboratories. Institutions, companies and government agencies operating more than one laboratory are now permitted to treat each laboratory separately in applying for priorities aid, though they may still "lump" them, if desired.

Under the amended order, references to NPA Regulation 4 (MRO) have been replaced with references to CMP Reg 5 (MRO which superseded the former on July 6).

Order M-71 was issued June 26, 1951, to enable laboratories to procure controlled materials and other products needed to carry on important research work through a self-certification of delivery orders.

Perry M Parrott

Joe M Ballentine

• Parrott and Ballentine to Represent Van Vlaanderen in South

Van Vlaanderen Machine Company, Paterson, N J, has appointed the newly-formed firm of Parrott and Ballentine, Greenville, S C, as sales agents in the Southern states for the New Jersey firm's complete line of dyeing and finishing equipment. The principals of the new firm, Perry M Parrott and Joe M Ballentine, have been in sales for the Smith, Drum Company for the past fifteen years. Prior to that time, Mr Parrott was with the Ralph E Loper Company, textile industrial engineers, Greenville, S C. Mr Ballentine was with Ware Shoals Manufacturing Company and with National Aniline Company.

The appointment is part of a general expansion of Van Vlaanderen's sales organization and is designed to give better sales coverage in the South. Previous coverage had been handled from Paterson .

• Sulfur, Sulfuric Acid Shortages Remain a Problem

The knottiest problem facing the chemical industry appears to be the shortage of sulfur and sulfuric acid, according to the Chemical Industry Advisory Committee and the NPA, though shortage of steel for expansion of production facilities and the growing impact of defense-rated orders are also causing concern. Shortages of sulfuric acid may restrict further increases in the production of synthetic detergents, to cite one example, that industry also requiring 15,300 tons a month—500 tons a month more than the 1950 rate of use. The supply picture of other raw materials in the manufacture of synthetic detergents looks brighter, however, according to NPA.

In discussing the shortage of sulfur and sulfuric acid, some committee members said their companies had been compelled to reduce production because of their inability to obtain these scarce materials. Most committeemen, however, said that although the situation had been a "touch-and-go" one, they have managed to get all the sulfur and sulfuric acid they needed.

NPA said there was some possibility of relieving the shortage through recovery of sulfuric acid from new sources—such as sour gas—and through conversion of equipment in some plants now using native sulfur, to enable them to use other sources. NPA also stated that the Defense Production Administration is considering a program for the distribution and uses of sulfur.

Briefly, this is the picture on other materials in short supply.

Napthalene—There isn't enough to meet demand now, but NPA said new production facilities are being brought in and that the supply will rise to meet demand.

Chlorine—There is a chronic shortage here, but a 50 percent increase in production capacity will do much to ease the situation, NPA said.

Styrene—The rubber program has put a squeeze on supply, but the situation is improving.

Benzene—Production will rise rapidly in the next two years. Meanwhile, importations have done much to fill the current gap between supply and demand.

Plastics—The old-line plastics have been sufficient to meet demand in most instances, but there has been some difficulty in the newer types, for which there has been a heavier demand than production facilities could meet.

NPA has also stated that dye production has been hobbled somewhat by the scarcity of sulfuric acid and that the steel shortage has caused a tight situation in the steel drums, tanks and other types of chemical containers.

Regarding the impact of defense-rated orders, NPA states that it is seeking a method of removing chemicals from DO application.

NAMES IN THE NEWS

• Interchemical Textile Colors Division Appoints Four New Executives

Interchemical Corporation, Textile Colors Division, Hawthorne, N J, has announced through Norman S Cassel, divisional president, four new executive appointments. JOHN ZELEK becomes vice-president in charge of research and development; ARTHUR BOOTH, vice president in charge of production; FRED BAUMANN, vice-president in charge of trade relations; and FRANCIS H BEBEE, administrative assistant to the divisional president.

John Zelek

Mr Zelek joined the Textile Colors Division (then Aridye Corporation) in 1945. Recently he has headed intermediate and dyestuff research and production. Earlier he was with Calco Chemical Division of American Cyanamid Corporation, Amalgamated Dyestuff and Chemical Works, and Chemical Manufacturing Company.

Arthur Booth

Mr Booth joined the Division in 1942. For the last several years he has headed research and production of the dispersions department. He began his career with Petroleum Derivatives Corporation, was subsequently associated with Dr James J Mackey as a consulting chemist to the textile indsutry, and from 1932 to 1942 was head of the Department of Textile Chemistry, Dyeing and Printing at Paterson Vocational School.

Fred Baumann

Mr Baumann joined the Division in 1938. He has been active in various phases of sales and sales management. Until 1943 he was concerned primarily with the introduction of Aridye Pigment Colors. Since then he has spearheaded the Division's expanding activities in the dyestuff field. Formerly he was associated with National Silk Dyeing Company, Arnold Print Works, and Susquehanna Silk Mills in executive capacities.

Francis H Bebee

Mr Bebee joined the Textile Colors Division last December. He entered the employ of Interchemical Corporation in 1937 and since that time has held a number of administrative and executive posts.

Messrs Zelek, Booth and Baumann all are members of the AATCC.

• Five New Chemstrand Appointments

Five appointments were announced by Osborne Bezanson, president of the Chemstrand Corporation during the month of August.

CARL O HOYER becomes director of the General Engineering Department. With Monsanto Chemical Company continuously since 1939, Mr Hoyer comes to Chemstrand from MCC's Plastic Division at Springfield, Mass, where he was division engineer in charge of design and maintenance.

DR FRANK J SODAY will direct research and development of synthetic fibers, including the new acrylic fiber, Acrilan. His laboratories will be situated at the company's headquarters in Decatur, Ala. Previous to joining Chemstrand, Dr Soday was research and development director for Lion Oil Company, El Dorado, Ark, for four years.

The appointment of R W SUDHOFF as associate director of development was announced on the 13th. Mr Sudhoff will also make his headquarters in Decatur. From the early stages, he has been associated with the development of Acrilan. Like Mr Hoyer, Mr Sudhoff comes to Chemstrand from Monsanto, where he has held various positions since 1929, most recently that of assistant director of research for Central Research Laboratories, Dayton, O.

ROY G HEMMINGHAUS will be plant manager of Chemstrand's nylon plant under construction at Pensacola, Fla. During the design, procurement and construction phases of the nylon project, Mr Hemminghaus will act as top coordinator for Chemstrand and will make his headquarters in Wilmington, Del. He recently completed 20 years of service with Monsanto, where his most recent position was general manufacturing superintendent of Monsanto's John F Queeny plant in St Louis.

Chief engineer of the nylon plant will be F G GRONMEYER. He will be located at the Pensacola site. Mr Gronmeyer recently completed 22 years with Monsanto, where his most recent assignment was that of chief engineer of the Organic Division.

• Forrest Named to PTI Foundation Directorship

Fred C Scholler, president of the Philadelphia Textile Institute Foundation, announced last month that RONALD C FORREST had been appointed executive director of the Foundation. Mr Forrest is known particularly for his activity in promoting the progress of various textile associations which he served as an official and executive.

John C Thomas

• Thomas New Berkshire Southern Representative

Berkshire Color & Chemical Co has appointed JOHN C THOMAS as southern sales and technical representative. Mr Thomas has a long and varied background in the industry in the South, his most recent associations being with North Carolina Finishing Co, where he was a dyer, finisher and research technician, and with Dan River Mills, where he worked with the research division.

Mr Thomas will make his headquarters in Salisbury, N C.

• Arnold, Hoffman Appoints Bruns Treasurer

HARRY G BRUNS, for six years trust officer of the Industrial Trust Company of Providence, R I, has been named treasurer of Arnold, Hoffman & Co, Inc. The American affiliate of Imperial Chemical Industries Ltd of Great Britain made the announcement recently through their president, Edwin H Arnold, who held the treasurership of the firm prior to the appointment of Mr Bruns.

Mr Bruns, a member of the New York bar, was formerly assistant trust officer of the Manufacturers Trust Company of New York.

The new appointment took effect on September 1st.

• Merry Joins Goedecke

MILTON MERRY, formally with the Sales Division of Burlington Mills Ribbon Corporation, has joined William F Goedecke, sales representative of Classe

• ACC Makes Several August Personnel Moves

Several important moves by American Cyanamid Company took place during August as follows:

SHELDON T DAHL was named West Coast Manager of the Industrial Chemicals Division and Plastics and Resins Division, where he will direct sales and promotion activties. HERBERT G PRATT was appointed manager of the San Francisco office of the Industrial Chemicals Division. Both men joined Cyanamid when the S T Dahl Company was acquired in 1948.

DR A J WEITH, with Cyanamid since 1937, was named product supervisor in the Synthetic Organic Chemicals Department of the Industrial Chemicals Division. He comes from the New York Sales Department, which assignment followed thirteen years in the Stamford Research Laboratories.

Effective August 1, RICHARD F WARREN became a senior market research analyst of the Market Research Section, New Product Development department. For the past five years, Mr Warren was market editor for *Chemical Engineering*.

To handle the management functions of the Arizona Chemical Company, three ACC executives were named. They are DR R C SWAIN, vice president in charge of research, who will supervise Arizona's research and process development; E D POWERS, vice president in charge of production, who will suprevise all of Arizona's manufacturing activities, and DR D H W FELCH, chief engineer, who will direct all engineering activities of the Arizona Company. The three men will retain their Cyanamid posts.

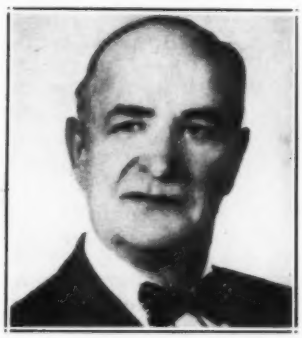
The Arizona Chemical Company, owned jointly by Cyanamid and the International Paper Company, converts by-products of International's Southern Kraft Division into crude talloil, refined grades of alpha-pinene, and beta-pinene. The appointments follow a recent major expansion of Arizona activities to include distillation of the crude talloil into rosin, fatty acids and refined talloil.

F M FARGO will continue as president of the company, J F FREDRIKSSON as vice president and general manager, and A SCHARWACHTER will remain in charge of sales.

• Erath Joins W, C & D

WILLIAM F ERATH has joined the technical and sales staff of Whittaker, Clark & Daniels, Inc, New York importers, manufacturers and exporters of minerals, colors and pigments. His experience in America's field of color dates to 1912 when his employers, the G Siegle Co (Germany), dry color manufacturers, sent him to their branch plant in Staten Island, N Y. He later operated a color laboratory and supervised sales work for Siegle in Chicago.

Mr Erath will again be associated with PAUL THOMASSET with whom he worked for 20 years at the Ansbacher Siegle Corp.



William F Erath

NEW PRODUCTS AND DEVELOPMENTS

• Interchemical Mildewproofing Agent Available in Several Forms

Interchem ® Copper-8-Quinolinolate, a recently-announced mildewproofing agent produced by Interchemical Corporation, Textile Colors Division, Hawthorne, N J, is now available against DO rated orders in water-dispersible and solvent-dispersible forms, as a concentrated dispersion in dioctyl phthalate, and in powder form. It is said to meet virtually all government specifications calling for the use of copper-8-quinolinolate.

• Richmond Develops Scour Bleach No 2

A new scour and bleach compound, Scour Bleach No 2, reportedly fills the need for a mild bleach to get a clear bottom for pastel shades or for bright colors on nylon and rayon. The product, which is manufactured by the Richmond Oil, Soap & Chemical Co, Inc, Philadelphia, is said to accomplish this in one operation.

Richmond states that it is particularly effective on both spun nylon and spun rayon.

• Water Soluble Copper and Zinc Napthenates

Caro CW and Caro ZW, water soluble stable forms of Copper 8 Naphthenate and Zinc 8 Naphthenate, have been developed by the Carolina Aniline & Extract Company, Charlotte 1, N C. The materials reportedly can be applied in any normal wet processing equipment and will meet government specifications for copper or zinc metallic content.

Leaching is reported to be 11%. It is stated that no fumes or fire hazards accompany the materials' use, the process being applied cold, and machines used can be cleaned with cold water.

Caro CW is said to contain 80%, by weight, of Copper 8 Naphthenate, equalling 6.4% copper as metal, by weight.

Caro ZW reportedly contains 90%, by weight, of Zinc 8 Naphthenate, equalling 7.2% zinc as metal, by weight.

Literature on the new materials is available from the manufacturer on request.

• Mandee Announces "Spot-Repellent" Finish

Mandee Fabrics, Inc, 1412 Broadway, New York, N Y, has announced a new spot and water repellent finish to be known as Manduro Plus Resist-A-Spot. It is reported to have satisfactorily undergone severe tests during the past year on various constructions, and to have received the Good Housekeeping Guaranty Seal, which provides for replacement or refund of money if not as advertised in *Good Housekeeping*.

The new finish will be featured on rayon coverts, rayon sheen gabardines and other suiting constructions, according to Arthur S Mandelbaum, president of Mandee Fabrics, Inc. Mr Mandelbaum states that the advantages of spot, stain and water repellency now used on suitings and other outerwear should provide an ideal springboard for promotional campaigns, in addition to the saving consumers can realize in their cleaning and pressing bills.

In addition to the product's ability to resist most non-oily food or beverage spots and stains, it is said to furnish a high degree of crease-resistance. Resist-A-Spot, a Permel Plus* finish, is presently being supplied by the Textile Resin Department of American Cyanamid Company.

The finish has been supplied on a pilot basis to a limited number of firms and may be seen this fall in ladies' suits, coats, sportswear and rainwear garments.

Large scale production in the spring for men's and children's garments is planned.

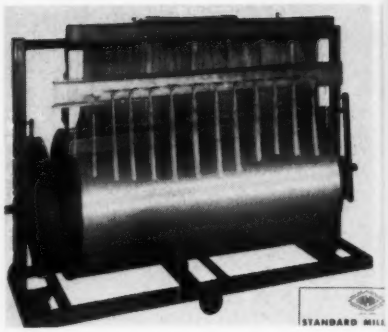
* Trademark of American Cyanamid Company.

• Portable Beam Truck

Standard Mill Supply Company, Pawtucket, R I, is now manufacturing the "Standard All-Steel Portable Beam Truck", a unit in which the beam is supported by the beam shaft, thereby avoiding damage or depression.

The trucks have only one moving part, with no part touching the yarn. The beam is put into the loom by gravity on a slight decline.

The upright frame part of the truck has a heavy cast iron adjustable bearing, which reportedly can be locked into position to take care of loom beams up to 30" diameter heads. The harness frame arms, attached to the top rod running lengthwise with the truck, will accomodate up to 25 harness frames, ½" thick, according to reports.



SMSC Portable Beam Truck

The casters are of the 4" Plaskite roller bearing stationery type and are equipped with thread guards.

TECHNICAL LITERATURE

Nitrosyl Chloride

The Solvay Process Division
Product Development Department
Room 1001
40 Rector Street
New York 6, N Y
Available on request.

This 80-page book gives a complete review of the properties and reactions of Nitrosyl Chloride. Its preparation in the Nitrogen Division Laboratory of the Allied Chemical & Dye Corporation by Drs Beckman, Fessler and Kise is said to have taken over four years, during which time well over 700 references and abstracts were studied, recorded and cross-checked. Half were in foreign languages and were examined in their original form.

Training for Success in the Textile Industries

International Correspondence Schools
Scranton 9, Pa
Available on request

This is a revised edition of the ICS Catalog, which outlines the new Textile Engineering Course in addition to other textile courses offered by the ICS School of Textiles.

Descriptions of course content are listed for manufacturing, engineering, carding, spinning, throwing, weaving, designing dyeing, maintenance, supervision and merchandising.

Two introductory sections "Where do you fit in?" and "Let's go through the mill" serve to aid the student in the selection of courses in aligment with future needs and desires.

Namico Soaps and Cleaners

National Milling & Chemical Co, Inc
4601 Nixon Street
Philadelphia 27, Pa
Available on request

This is a complete catalog of National Milling's line of soaps and cleaners dealing with characteristics, recommended uses and other data on each product.

Of chief interest to the textile wet processor are the following: Triumph Flakes (77% soap, 39 titer), for high and medium temperature use; Wabash Flakes, 88% soap, 39 titer; Wabash Powder, 92% soap, 39 titer; Namico "42" Flakes, 88% soap, 42 titer; Namico "42" Powder, 92% soap, 42 titer; Green Bar, for cold water washing; Sure Suds; and Detergent S.

Comparison Measurement of Two Independent Variables

Minneapolis-Honeywell Regulator Company
Brown Instruments Division, Station 40
Wayne and Windrim Aves
Philadelphia 44, Pa
(Available on request)

Instrumentation Data Sheet 10.0-6 describes the new duplex *ElectroniK* recorder which simultaneously plots two totally independent variables on one chart. The instrument embodies two complete measuring systems and recorders which can be actuated from any d-c source.

The Instrumentation Data Sheet describes the operation and constructional features of the instrument together with numerous applications for which it is adaptable.

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BOUND BROOK, NEW JERSEY

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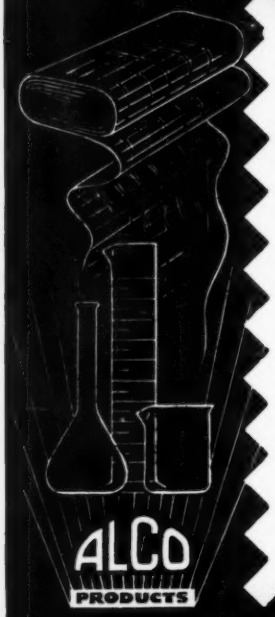

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* * *

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NaCl	0.40
Other Na_2O (not oxidizable)	1.35
Na_2S	61.00

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IN CANADA: Chemical Developments of Canada Limited, Leaside, Toronto 17

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Polysize Resins for Textile Finishers in emulsion form, deposit colorless glass-clear films which do not affect the color values of the material. Polysize resins are completely pre-cured; and only drying is required to set the resins.

POLYCO dispersions are adaptable to all the common methods for finishing textiles — padding, tumbling, spraying, knife coating and roller coating. The usual methods for drying employed in the textile mill — can, festoon, tenter frame and boarding — can be used for drying treated materials; they will in no way harm the resin finish.

POLYCO emulsions render an improved appearance to printed cotton goods, and good adhesion is possible to natural or synthetic fibers.

POLYCO RESIN 953-7A is unmatched for its wash resistant quality and stiffening properties.

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- ★ No increase in flammability of textiles
- ★ Will not discolor, cloud or alter dyes used for textiles
- ★ Resistant to mildewing, rotting and souring
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- ★ Complete application in a "one-bath" process
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- ★ Improve tensile strength and abrasion resistance
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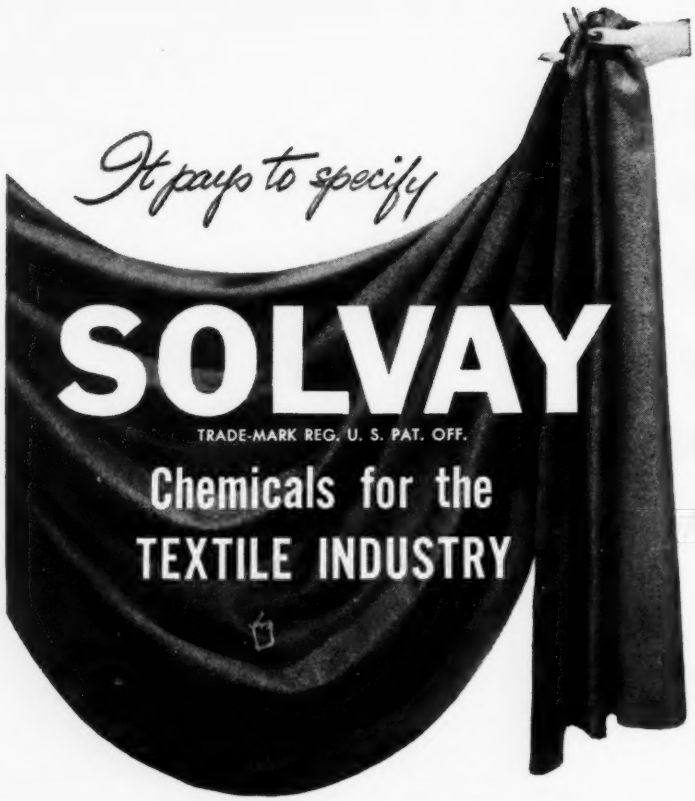

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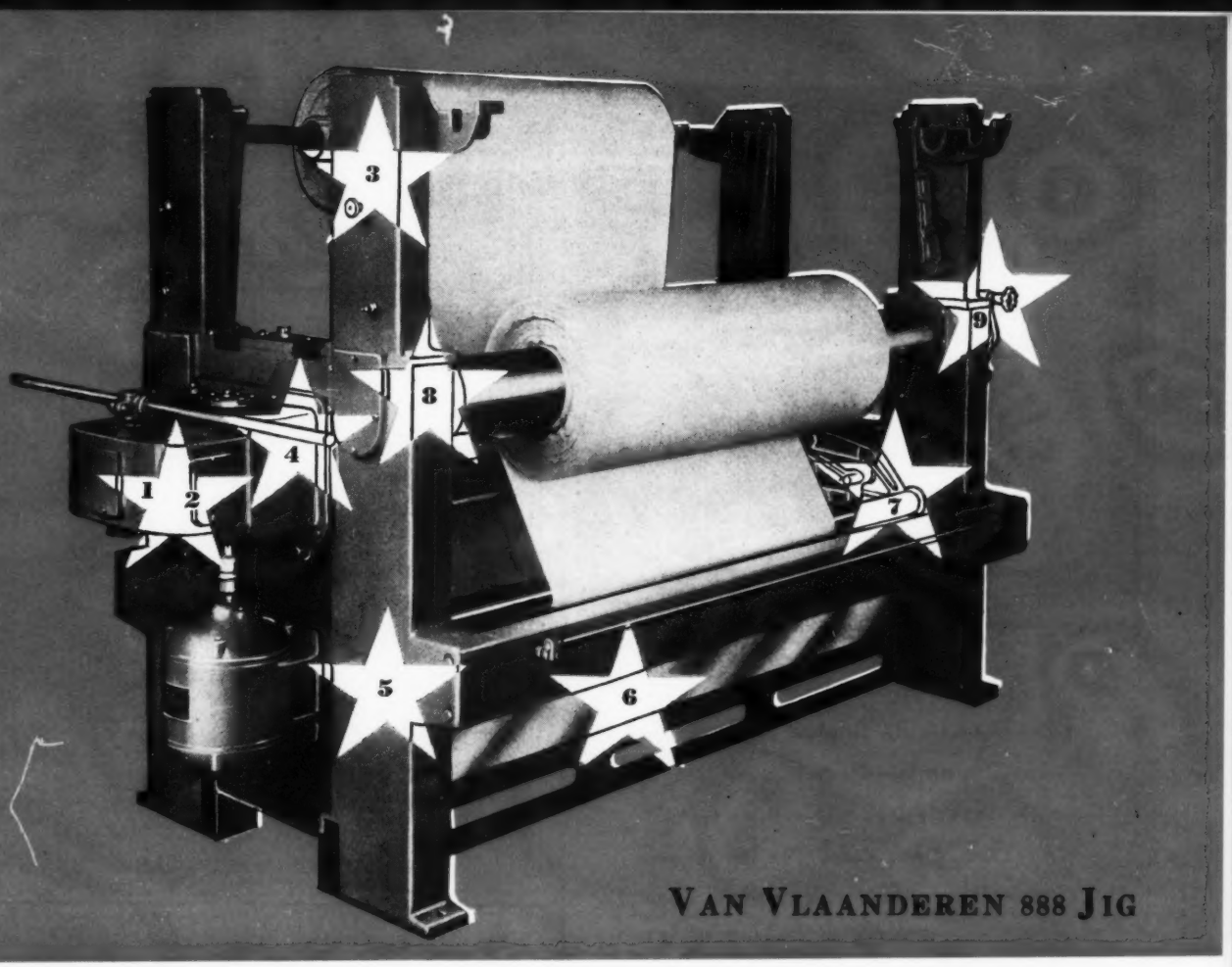

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STAR PERFORMER

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2. Multiple disk friction clutches (dry type) eliminate drag entirely.
3. Multiple roller chain drives completely housed and running in oil reduce maintenance and assure clean operation.
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5. Heavy vibration free cast iron frames and separators.
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8. Rubber covered jig rolls mounted on anti-friction bearings.
9. New malleable iron brakes with tension indicator permit quick and accurate control.

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You are invited to see this machine.

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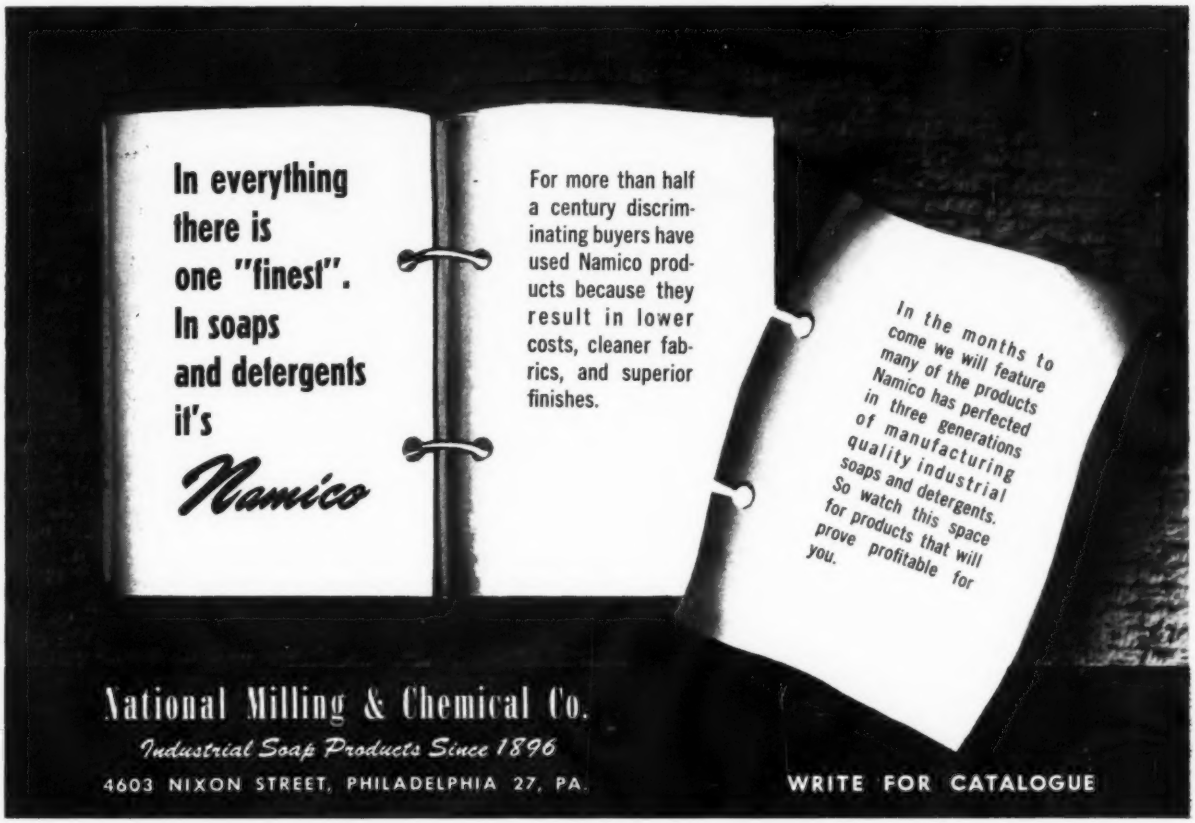
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They completely and permanently soften hardest water *without* precipitation.

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- **...assure cleaner fibers, deeper dye penetration, level dyeing**
- **...improve cleaning and foaming action of synthetic detergents**
- **...prevent and/or remove iron stains in *any* caustic solution**
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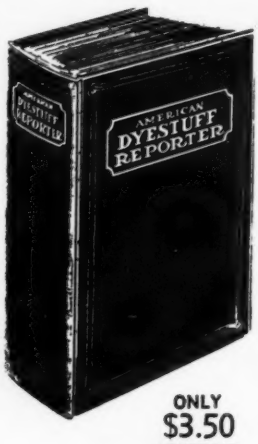

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CHEMIST: Established dyestuff manufacturer requires a Textile Chemist with laboratory and/or plant experience in dyeing synthetic fibers for a responsible position in their New York Laboratory. Write Box No. 166.

FOR SALE: Garment Dyehouse. Location: Boston, Mass. Yearly gross: $15,000. Excellent for experienced dyer desiring own business with possibility of future expansion. Write Box No. 172.

POSITION WANTED: Textile chemist with broad experience in the development and production of textile chemicals seeking responsible position with commensurate salary. Opportunity for firm to acquire service of top-notch plant chemist. Would also be interested in producing on salary with opportunity of becoming part of firm. Write Box No. 176.

POSITION WANTED: Personable — ambitious — able young man desires change of position to enable fuller use of talents. Excellent technical background advanced degree chemistry and textiles. Four years' experience running jig dye plant. Experience includes all classes and types of dyeings — direct, vat, sulphur, napthol — on cotton, acetate and viscose rayon. Write Box No. 178.

POSITION WANTED: Chemist with B.S. degree from textile school seeks responsible position. Six years' mill experience, dyeing, bleaching, mercerizing and printing. Excellent lab background, familiar with all types of dyestuffs, testing, evaluation and application. Good color-matcher, cotton, wool and synthetics. One year technical service work with a shrink-resistant wool program. Write Box No. 179.

WANTED: Southern district salesman and northern district salesman with technical background and experience in textile dyeing and finishing to handle sales and technical service for dyes. State age, education and experience. Compensation dependent on experience and past record. Replies will be held in strictest confidence. Write: Pittsburgh Coke & Chemical Company, Fine Chemicals Division, Pittsburgh 25, Pa.

WANTED: Unusual opportunity for a dyer with thorough experience with vat and napthol colors on cotton drapery material. Must possess initiative and manage medium sized dye house responsibly. Experienced with mercerization desirable. Only first class top man may apply. Pleace give outline of experience, references and salary in first letter. Paterson, New Jersey, area. Write: P. O. Box 204, Clifton, New Jersey.

POSITION WANTED: General manager of flax hemp jute and hard fiber spinning, rope twine and thread-washing. Practical experience in United Kingdom, Europe and America. Many years in charge of large plants. Wishes to hear of opening where experience and initiative will be suitably rewarded. Write Box 180.

POSITION WANTED: Young man, 33, married, thoroughly experienced textile analytical laboratory. Resumé on request. Write Box 181.

POSITION WANTED: Experienced dyer of acetate, viscose and nylon on boxes and jiggs. B.S. degree in textile chemistry and coloring. At present employed as assistant to superintendent. Wish to locate in upper New York State—married veteran. Write Box 182.

SALES EXECUTIVE: Dyestuffs and Chemicals: Many years successful sales, promotion and policy-making of same to textile industry. Currently directing sales with satisfied national dyestuff and chemical manufacturers but am not exercising ability anywhere near capacity. Creative developer, cultivator, cooperative, personable, aggressive and ambitious. Married, forty years of age. Available on 2 or 3 months' termination notice. Will reply to principals only. Write Box 183.

POSITION WANTED: Textile colorist — 30 years' experience on rayon, cotton, raw silk, nylon, yarns with vat, develop, acetate, sulphur, acid, direct dyes. Will locate anywhere. Write Box 184.

TEXTILE ENGINEERS

Men for technical service and development work with company engaged in manufacture and development of new synthetic fibers. Candidate must have minimum of B.S. degree in textiles, chemistry or engineering followed by two to five years of experience in the textile industry. State age, education, experience and references. Write Box 185.

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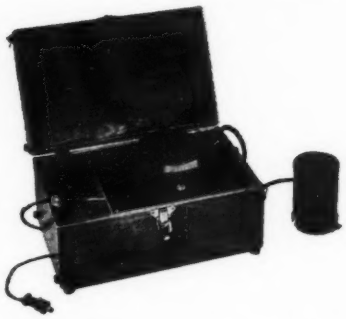

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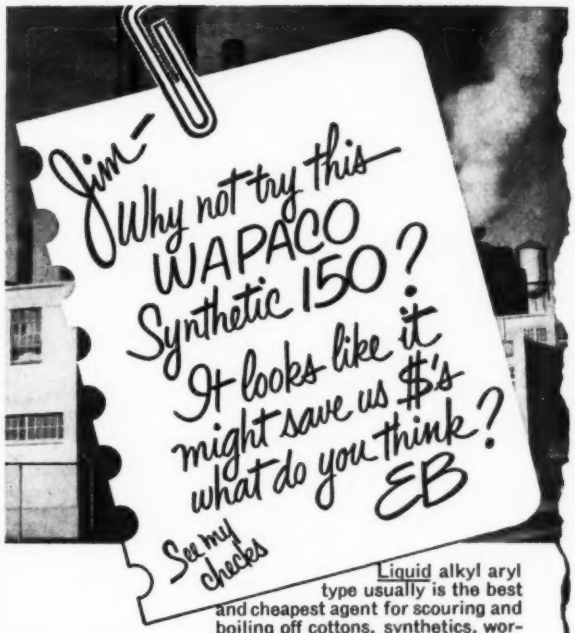

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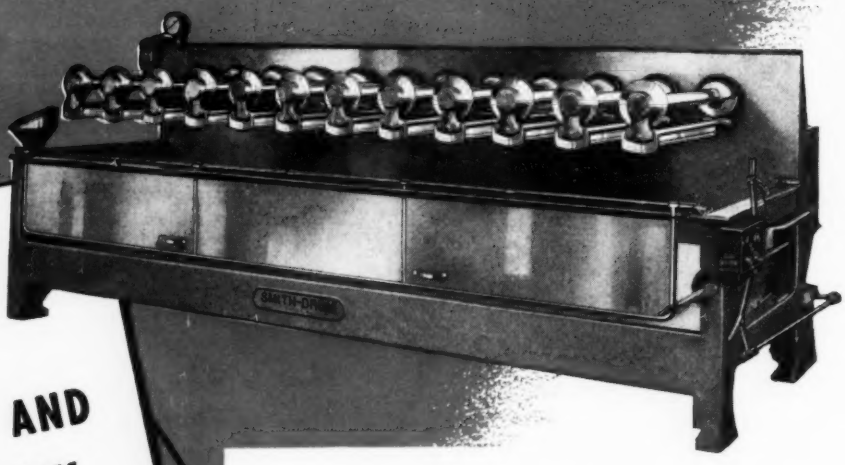

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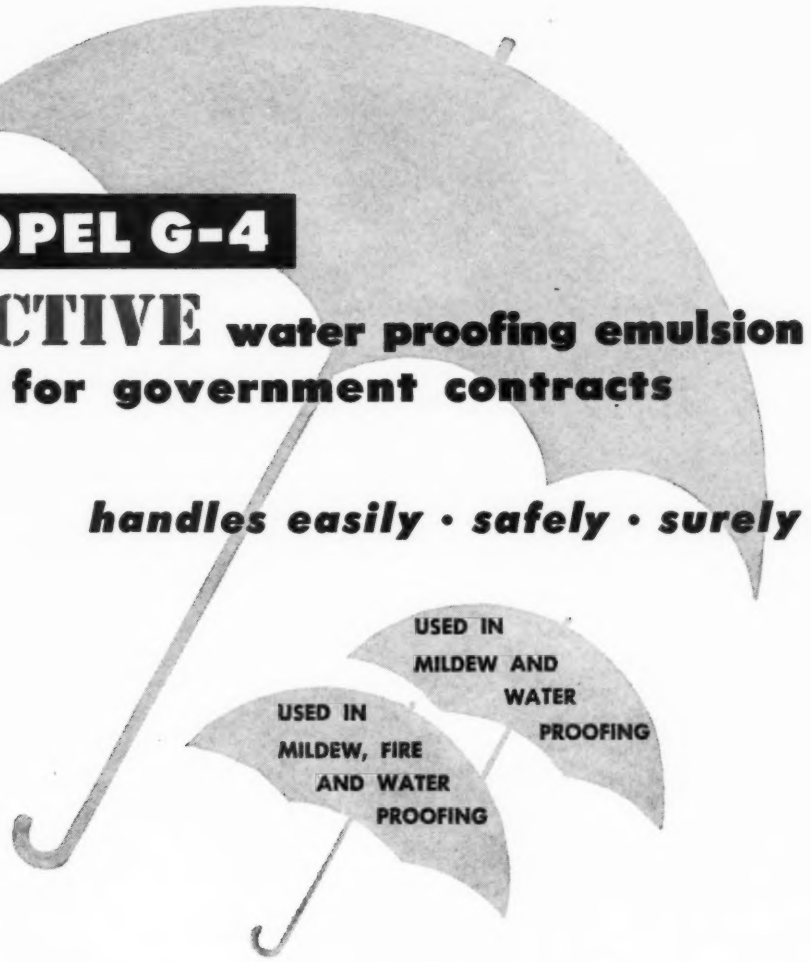

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